Greenhouse Gas Reduction Strategy Alternatives: Cost-Effectiveness Analysis

A report produced for the Boston Region Metropolitan Organization

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A Report for the Boston Region MPO

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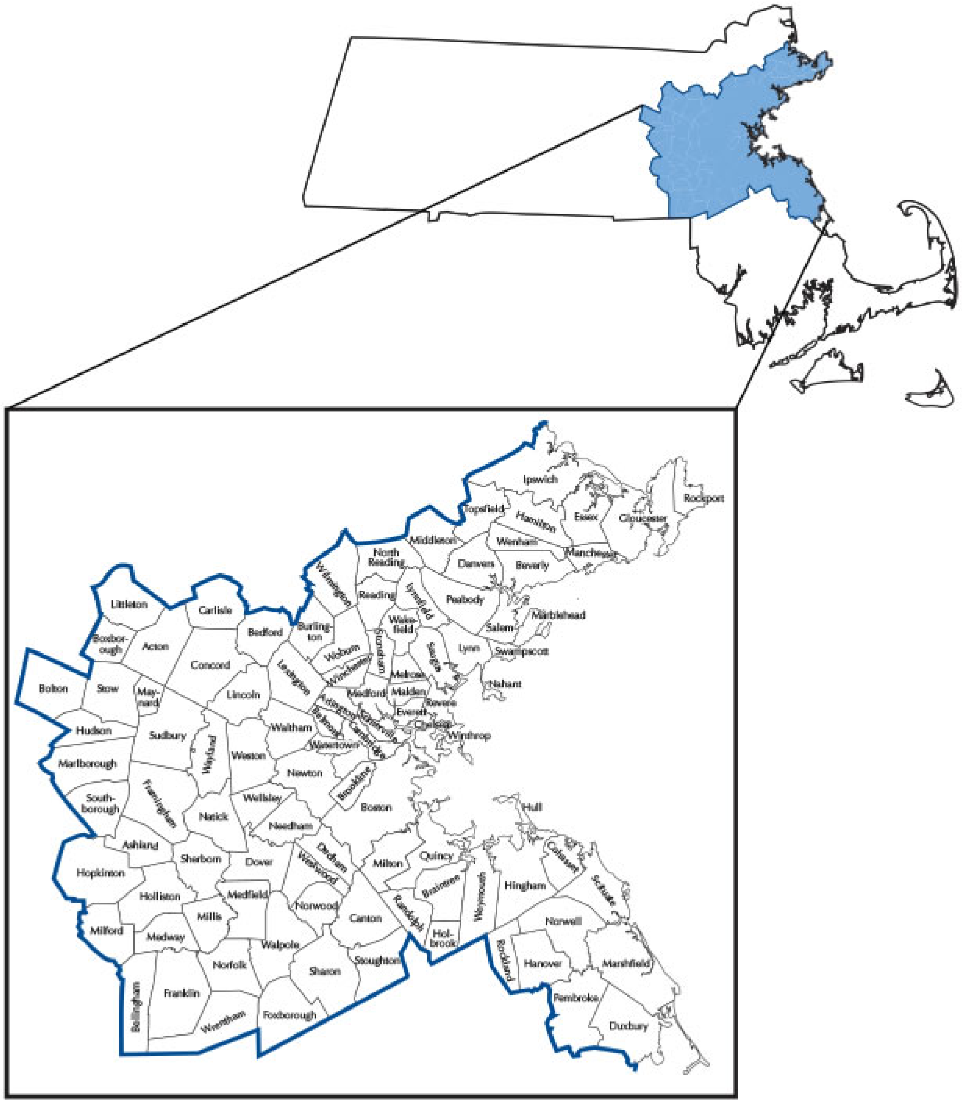

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ABSTRACT

This report provides information about various transportation strategies that support reduction of GHG emissions. This will help the Boston Region MPO to identify transportation investments that are the most cost-effective in reducing GHG emissions. Some examples of GHG reduction strategies are projects that shift travelers from single-occupant vehicles to biking, walking, or transit.

This report includes a literature review and research into work performed by federal, state, and regional transportation agencies; universities; and advocacy and nonprofit organizations that could yield information on GHG impacts and costs of implementing various reduction strategies across all transportation modes. MPO staff inventoried past and current MPO programming within the context of these strategies and quantified the projected GHG impacts using various tools. MPO staff then calculated the cost-effectiveness of each transportation strategy and identified those strategies that are most effective at reducing GHG emissions.

In addition, this report summarizes ongoing work that will provide further information to help the MPO make informed decisions when prioritizing and funding projects, programs, and studies to reduce GHG emissions in the future. It also discusses next steps that the MPO can take to include GHG reduction as part of its decision-making process.

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Executive Summary

ES.1 MPO ROLE IN GHG REDUCTION

This study was undertaken to provide information about cost-effective greenhouse gas (GHG) reduction strategies to help the Boston Region Metropolitan Planning Organization (MPO) make informed decisions when prioritizing and funding projects, programs, and studies to reduce GHG emissions in the future. The MPO acknowledges that climate change likely will affect the Boston region significantly if climate trends continue as projected. In order to minimize the negative impacts, the MPO is taking steps to decrease our carbon footprint while simultaneously adapting our transportation system to minimize damage from natural hazards. The MPO has several tools at its disposal to support reductions in GHG emissions that are produced by the region's transportation system, including the MPO's:

- Capital-investment funds allocated through the Long-Range Transportation Plan (LRTP) and the Transportation Improvement Program (TIP)
- Planning and research funds, which are described in the Unified Planning Work Program (UPWP)
- Public outreach and involvement tools, which are supported with UPWP funds and can be used to disseminate information
- Potential role as an advocate for various transportation policies and practices

Using its vision, goals, and objectives, the MPO considers projects and strategies that protect and enhance the environment. One goal is Clean Air and Clean Communities with an objective to "reduce greenhouse gases generated in the Boston region by all transportation modes as outlined in the Global Warming Solutions Act."

ES.2 LITERATURE REVIEW

One objective of this study was to research literature about GHG-reduction strategies, in order to understand their potential to reduce greenhouse gas emissions and their cost-effectiveness in terms of implementation costs. Twenty-three strategies were identified that fall into three categories (required employer-offered compressed work week and compressed workweek: mandatory public and voluntary private are separated resulting in 24 strategies in Appendix A):

- Creating a more efficient transportation system that has lower GHG emissions
- Promoting fuel efficiency and cleaner vehicles
- Coordinating transportation with land use decisions

Of these strategies, it was determined that the MPO could support 14 either through funding in the LRTP and TIP, study through the UPWP with eventual funding for implementation in the LRTP or TIP, and publicizing through public outreach. Table ES.1 shows the 23 strategies with the MPO fundable strategies in green. Strategies that the MPO could study that are not in green would require a partnership with another agency in order to implement that strategy. Also included in the table are rankings for potential GHG reductions and the average direct cost-effectiveness of strategies for which cost information was available. The rankings of the GHG and cost-effectiveness information are outlined in section 4.2 of the report.

TABLE ES.1
Twenty-Three Promising Strategies by Type, Potential MPO Role in Implementation, and GHG and Cost-Effectiveness Ranking (Based on National Data)

Category	Strategy	Strategy Type	Potential MPO Role	GHG Ranking*	Cost Ranking**
Creating a More Efficient Transportation System that Has Lower GHG Emissions	Pedestrian Improvements	Transportation System Planning, Funding, and Design	Fund or Study	14	13
	Bicycling Improvements	Transportation System Planning, Funding, and Design	Fund or Study	19	12
	Workplace Transportation Demand Management	Travel Demand Management	Fund or Study	13	9
	Teleworking	Travel Demand Management	Fund or Study	11	17
	Individualized Marketing of Transportation Services	Travel Demand Management	Fund	17	8
	Ridesharing	Travel Demand Management	Fund or Study	24	7
	Car Sharing	Travel Demand Management	Fund or Study	23	4

Category	Strategy	Strategy Type	Potential MPO Role	GHG Ranking*	Cost Ranking**
	Compressed Work Weeks	Travel Demand Management	Study	5/15	1
	Expansion of Urban Fixed-Guideway Transit	Transportation System Planning, Funding, and Design	Fund or Study	10	18
	Rail Freight Infrastructure	Transportation System Planning, Funding, and Design	Fund or Study	21	11
	Increased Transit Service	Transportation System Management and Operations	Fund or Study	12	19
	Transit Fare Reductions	Transportation System Management and Operations	Study	16	16
	Pay-As-You-Drive Insurance	Taxation and Pricing	Study or Advocate	3	6
	Vehicle-Miles-Traveled Fees	Taxation and Pricing	Study or Advocate	6	10
	Congestion Pricing	Taxation and Pricing	Study or Advocate	8	14
	Carbon Tax or Cap-and-Trade	Taxation and Pricing	Study or Advocate	1	NA
	Alternative Construction Materials	Construction Practices	Advocate	9	15
Promote Fuel Efficiency and Cleaner Vehicles	Truck-Idling Reduction	Transportation System Management and Operations	Fund or Study	18	5
	Reduced Speed Limits	Transportation System Management and Operations	Study or Advocate	7	3
	Driver Education and Eco-Driving	Public Education	Publicize	2	N/A
	Information on Vehicle Purchases	Public Education	Publicize	20	N/A

Category	Strategy	Strategy Type	Potential MPO Role	GHG Ranking*	Cost Ranking**
Coordinate Transportation with Land Use Decisions	Compact Development	Land Use Policies	Study or Advocate	4	2
	Parking Management	Land Use Policies	Fund or Study	22	NA

*GHG Ranking is from most effective to least effective in reducing GHG emissions.
**Cost Ranking is from the most cost-effective to the least cost-effective in reducing GHG emissions.
Note: Green text indicates that a strategy can be funded by the MPO.
Source: Central Transportation Planning Staff.

As shown in the table, each category is broken down into strategy type:

1. Creating a more efficient transportation system that has lower emissions
    - Transportation System Planning, Funding, and Design Transportation System Management and Operations
    - Travel Demand Management
    - Taxation and Pricing
2. Promoting fuel efficiency and cleaner vehicles
    - Transportation System Management and Operations
    - Public Education
3. Coordinate transportation with land use decisions
    - Land Use Policies

The majority of the strategies fall into “creating a more efficient transportation system” category. The pricing strategies, such as cap-and-trade or carbon tax, congestion pricing, pay-as-you-drive insurance, and VMT fee, have the most potential to reduce GHG emissions. The MPO does not have the authority to implement these programs. Thus, for these strategies, it may be appropriate to advocate for implementation to whichever local, State, or Federal body that has jurisdiction. For example, a carbon tax or cap-and-trade policy could greatly benefit greenhouse gas reduction in transportation, but would fall under national or state jurisdiction. The MPO could, however, study or advocate for the programs.

The MPO can implement a number of other strategies in this category. Infrastructure investments in transit, walking, bicycling, and rail facilities and improvements to transit service (transportation system planning, funding, and design and transportation system management and operations) are needed to strengthen low-carbon transportation choices; however, they are at the mid-to-lower end of strategies that are both GHG and cost-effective.

Many of the travel demand management strategies that the MPO could fund rank lower in GHG reduction, but many are more cost-effective than the infrastructure projects. Both the infrastructure and the travel demand management strategies should not be discounted in importance because of their smaller relative potential for reductions or lower cost-effectiveness. These strategies can affect the success of others, or are important for balancing equity and other needs of the transportation system as a whole. Some of the least-cost effective strategies, namely the transit-focused strategies and teleworking, have the ability to achieve larger reductions in total; without these strategies, larger emission reductions might not be achieved. In addition, both the transit strategies and teleworking have many other benefits that support cost expenditure, in addition to GHG reduction. These strategies have important mobility and accessibility benefits.

The MPO can publicize two of the strategies that fall under the “promoting fuel efficiency and cleaner vehicles” category. Driver education/eco-driving can play a big part in reducing greenhouse gas emissions from transportation; however, the MPO can only publicize and promote this program for its GHG benefits. The MPO could consider seeking funding partnerships to deploy driver education or eco-driving. It also could study truck-idling reduction and potentially fund the purchase of idle reduction equipment for trucks through its CMAQ program. The MPO could study the effects of implementing reduced speed limits, but this strategy would ultimately need to be enforced through the local and state police.

All strategies, in the “coordinating transportation with land use decisions” category, will require partnerships or strengthened collaboration across agencies. For instance, MAPC develops the land use plan for the region, so it is better positioned to support the compact land use strategy. Ultimately, local entities would need to implement any land use changes in their municipalities. Compact development not only has the potential to achieve the fourth-largest GHG reductions, but also could affect the strategies that the MPO can directly implement—transit infrastructure improvements and walking and bicycle facilities. This strategy highlights the benefits of the MPO/MAPC partnership.

Partnering may be advantageous for strategies that the MPO can study. For example, MAPC has already worked with communities in the Boston region to improve parking management. The MPO may be able to use its transportation expertise to support its existing work further by coordinating with MAPC to study promising parking policies under consideration so they can be implemented by municipalities.

Another example, the workplace transportation demand management and outreach campaigns and incentives strategies could benefit and expand from the existing work of MassRIDES and transportation management associations. The MPO's new Community Transportation program can help to provide CMAQ funding for startup shuttle-service operations.

Deployment of some of the greenhouse gas reduction strategies discussed in the literature review would represent change in the MPO's historical funding patterns. The MPO may consider forging new partnerships for implementation or funding of strategies. As noted in the literature review, all of the strategies could benefit from further research. Data about which strategies Massachusetts is implementing could make for better-informed decision making. Further research is needed to quantify the potential emissions reductions at the state and metropolitan regional levels.

ES.3 EVALUATION OF MPO INVESTMENTS

In developing its current LRTP, *Charting Progress to 2040*, the MPO re-evaluated its past practices and set a new course by moving away from programming expensive capital-expansion projects to ease congestion, instead setting aside more funding for small operations-and-management projects that support bicycle, pedestrian, and transit, along with fewer major roadway improvements. This is in line with greenhouse gas emissions-driven decision making. This type of funding plan is compatible with some of the strategies discussed in the literature review, especially if highway funds are flexed to transit projects.

Many of the projects that have been funded in past TIPs fall into the Intersections Improvements, Complete Streets, and Bicycle and Pedestrian improvements investment programs. Shuttle services have been funded in the past under older Suburban Mobility and Clean Air and Mobility programs—any new shuttle service projects now would fall into the new Community Transportation investment program. In the past, the MPO flexed highway funding to major infrastructure transit projects including the completed Assembly Square MBTA station and the proposed Green Line Phase II project extending the Green Line from College Avenue in Somerville to Mystic Valley Parkway in Medford.

Staff analyzed the projects that were funded or proposed for funding in past TIPs to determine their GHG and cost-effectiveness impacts. GHG emissions can be estimated using the travel demand model for highway and transit major infrastructure projects that meet capacity-adding characteristics. The majority of capacity-adding projects funded by the MPO have been analyzed as a bundle as

part of the LRTP using the travel demand model, a procedure that does not allow staff to associate a GHG reduction with a particular project. Although select major infrastructure projects have been analyzed for GHG benefits if a project-level analysis was performed by CTPS, this work used a variety of emissions factors developed through older emission models. Work that is more recent is underway; however, that work was not completed in time to include it in this report.

Given the limited availability of comparable regional model results using the same emissions model, the cost-effectiveness analysis focused on the projects that were analyzed using off-model spreadsheet analyses. The analyses included projects that were funded in the TIP under the MPO's four investment programs:

- Complete Streets
- Intersection Improvements
- Bicycle and Pedestrian Multi-Use Paths
- Shuttle Bus Services funded under the former Suburban Mobility or Clean Air and Mobility programs

For intersection and Complete Street projects, the cost per ton of GHG reduction varies widely, much more so than the construction cost per lane-mile. Projects that substantially improve a roadway's efficiency also tend to be cost-effective with a low cost per ton of GHG reduction.

The location of the project is also important. Projects located in the Inner Core and Regional Centers communities usually have higher construction costs per lane-mile than projects in the Maturing Suburbs and Developing Suburbs. However, the average tons reduction per lane-mile is greater for both the Inner Core and Regional Centers than for the Maturing and Developing Suburbs. Both of these differences may be attributed to the higher density of these more urbanized communities. Higher urban density usually implies higher construction costs as well as higher traffic volumes being funneled through inefficient roadway subsystems.

The higher average construction costs and efficiency benefit of the urbanized groups roughly balance out, and the average cost per ton of annual GHG reduction is similar for the Inner Core, Regional Centers, and Maturing Suburbs. The lower average cost-effectiveness in the Developing Suburbs may be attributable to lower traffic volumes in these communities.

Multi-use paths are used by pedestrians, bicycles, and other non-motorized vehicles. Unlike the roadway programs, GHG reductions from these projects do not reflect improved traffic efficiency. Instead, the construction of a multi-use path is assumed to make the non-motorized modes more attractive. The annual GHG reduction reflects an estimate of mode shifts away from auto across the projects.

See Table ES.2 for results of the analyses of the three investment programs.

TABLE ES.2
Projected Greenhouse Gas Reductions by Type of Investment Program
(All Costs are Thousands of Dollars)
(All Tons are Tons/Year)

Type of Program	Cost	Lane-Miles	Tons GHG	Cost per Lane-Mile	Cost per Ton	Tons per Lane-mile
Intersections	$35,804	8.88	4,813	$4,032	$7	542
Complete Streets	257,531	85.66	11,995	3,006	21	140
Multi-use Paths	41,174	21.80	1,055	1,889	39	48
All Programs	$334,509	107.46	13,050	$3,113	$26	121

Source: Central Transportation Planning Staff.

While costs and cost-effectiveness will vary widely within the three investment programs, the relationships of the program averages shown in Table ES.2 make sense intuitively. Much of the inefficiency of regional traffic is the result of obsolete and poorly designed intersections. Investing in only those lane-miles required to undertake the intersection program would reduce the most amount of GHG for the least cost. As noted in the literature review, transportation system management strategies, such as signal control management and integrated corridor management have the ability to achieve moderate GHG reductions. However, some roadway system-focused strategies have little or no ability to reduce emissions once induced demand is included the analysis.

At the opposite extreme are investments in multi-use paths. Most of the user benefits accrue to existing bicyclists and pedestrians, and the GHG reductions shown here are achieved only by attracting incremental users abandoning the auto mode.

The fourth investment program included shuttle services. Shuttle services can affect the success of other more cost-effective GHG strategies by balancing equity and other needs of the transportation system as a whole. They can offer other significant benefits including mobility, transportation equity, and livability. The service allows people who would ordinarily drive to their destination the

option to leave their car at home and use public transportation. The results of the shuttle service analysis are shown in Table ES.3 (assuming the net emissions from new shuttles and vehicle miles saved from private automobiles).

TABLE ES.3
Projected Greenhouse Gas Reductions from MPO-Funded Shuttle Services

Sponsor	Service	Total MPO Investment	Net CO_2 Tons/Year	Initial MPO Cost/Tons per Year
MetroWest	Route 7	$43,438	42	$1,042
MetroWest	Woodland Service	139,000	147	947
Cape Ann Transportation Authority	Stage Fort	8,000	7	1,214
Acton	Dial-a-Ride	65,993	48	1,363
Acton	Park and Ride	52,993	94	561
GATRA	Franklin Service	175,655	30	5,852
GATRA	Marshfield/Duxbury Service	186,608	146	1,280
Combined		$671,687	514	$1,307

GATRA = Greater Attleboro-Taunton Regional Transit Authority.
Source: Central Transportation Planning Staff.

Funding this type of service is the most cost-effective to the MPO in reducing GHG when compared to the other three types of investments (Complete Streets, Intersections, and Bicycle/Pedestrian). This is because the MPO provided the startup funding for these services but the sponsors continue to support the services to realize mobility benefits, which continue to result in GHG reductions.

Finally, MassDOT performed a GHG analysis for projects that were included in its 2013−2019 Statewide Transportation Improvement Programs grouped into similar investment programs as the investment programs used by the Boston Region MPO. The only difference was that MassDOT's calculations were done over the useful life of the project, while the MPO's analysis shows the reductions for the project's first year. The useful life for highway, bicycle, and pedestrian projects was 50 years and the useful life for transit projects was 15 years.

Table ES.4 shows a comparison of statewide and MPO cost-effectiveness calculations with the projects in descending order from projects that are most cost-effective to those with a lower impact. The MPO information presented earlier in this section was revised to useful life to show a comparison with the statewide results.

TABLE ES.4
Cost-Effectiveness of Statewide and MPO Investment Programs

Investment Program	Dollars of Investment (Tons per Year)	Dollars of Investment (Over the Useful Life)
MPO Shuttle Startups	$1,307	$87
MPO Intersections	7,000	140
MA Bus Service Expansion and Bus Replacement	9,850	197
MPO Complete Streets	21,000	420
MPO Bicycle/Pedestrian	39,000	780
MA Traffic Operation Improvements	43,200	864
MA Bicycle/Pedestrian	151,550	3,031

Source: Central Transportation Planning Staff.

As shown in the table, when comparing similar investment programs between the MPO and the state as a whole, the Boston Region MPO area has a lower cost per ton, which can be attributed to Boston's greater density, and greater use of the facilities.

ES.4 ONGOING WORK

Several activities are underway at both the state and MPO level that will help the MPO in making decisions to fund the most cost-effective projects to reduce GHG emissions. These are described below.

- First-Mile and Last-Mile Transit Connections Study (MPO Initiative): As part of this study, the MPO staff is assisting municipalities, Transportation Management Associations, or other service providers that request planning support for addressing first- and last-mile connections to transit. Candidate locations are being identified through outreach to MAPC subregions and other MPO outreach activities. For identified locations, MPO staff will document existing conditions, including barriers and opportunities for linking residential, commercial, and employment areas to transit services and stations, and will propose services that could fill the gaps. Staff also may recommend improvements to support access for pedestrians and bicyclists, where applicable.

- Focus40, MassDOT's vision for MBTA's investments: MassDOT and the MBTA are in the process of developing a 25-year strategic vision for MBTA transit investments. Once completed, MassDOT and the MBTA will work with the public and stakeholders to develop and evaluate different

investment strategies to address current and future needs. This information will help the MPO to determine projects that could be funded by the MPO in later years. Transit will help the MPO to achieve its Capacity Management and Mobility goal its Clean Air and Clean Communities goal, specifically by reducing GHG.

- MassDOT Capital Investment Plan: Once the CIP is completed, the MPO will have information about projects and programs that the state will fund over the next five years. This will allow the MPO to consider projects that were not part of the CIP, and which it may want to fund under the MPO target program to help move toward its objective of reducing GHG emissions.

- MassDOT is in the process of identifying new tools and developing practices to comply with federal and state laws to assess, track, and reduce GHGs from MassDOT and MPO transportation projects.

Once this work is completed, staff will update the MPO on the outcomes of these activities.

Chapter 1—Background

1.1 THE ROLE OF GREENHOUSE GASES IN CLIMATE CHANGE

Climate change refers to any significant change in an aspect of climate—such as temperature, precipitation, or wind—that lasts for an extended period. Air temperature is affected by certain gases in the atmosphere, in which heat may become trapped and accumulate near the earth's surface, causing what is known as a greenhouse effect. A similar effect occurs in greenhouses: The glass allows the sun's rays in, but much of the heat from the rays becomes trapped inside the structure; hence the term, greenhouse gas (GHG). If atmospheric concentrations of GHGs rise, they trap heat in the lower atmosphere and gradually increase average temperatures.

Currently, the earth is experiencing rapid climate change, some of which is a result of increased human activities that cause global warming. The extraction and combustion of fossil fuels like coal, oil, and natural gas is one example of a human activity that contributes to climate change. Transportation is one of the largest sources of greenhouse gases, with motor vehicles burning gasoline and diesel and releasing GHGs such as carbon dioxide, the most common GHG. As much as one-third of GHG emissions in the United States (US) are associated with transportation.

Climate projections from the Northeast Climate Impacts Assessment (NECIA) found that, temperatures across the Northeast could increase by 2.5° Fahrenheit (F) to 4°F in winter and 1.5°F to 3.5°F in summer over the next several decades. These temperature increases will occur regardless of the emissions choices we make now because of the heat-trapping emissions released in the recent past. However, by mid-century and beyond, "today's emissions choices generate starkly different climate futures." By late this century, if global GHG emissions were reduced sharply, winters would be projected to warm by 5°F to 7.5°F and summers by 3°F to 7°F. In contrast, by late this century if GHG emissions were not reduced, winters would be projected to warm 8°F to 12°F and summers by 6°F to 14°F.[1]

[1] Frumhoff, P. C., et. al., *Confronting Climate Change in the U.S. Northeast*, 2007, Northeast Climate Impacts Assessment Synthesis Team, p. ix, http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/pdf/confronting-climate-change-in-the-u-s-northeast.pdf.

What do these projected temperature increases mean for Massachusetts? Boston should experience a coastal flood equivalent to today's 100-year flood every two-to-four years on average by mid-century, and almost every year by the end of the century.[2] Inland areas also are at risk for more flooding, as rainfall should become more intense and more frequent. The number of heavy-precipitation events in the Northeast should increase 8 percent by mid-century and 12-to-13 percent by the end of the century.[3] Flooding can block or wash out roads and damage subway infrastructure.[4]

Transportation and Flooding

"In 1996, heavy rains raised the level of Boston's Muddy River, flooding a tunnel entrance to the 'T,' the city's subway system. The damage from this flooding closed a busy subway line for several weeks and cost the city roughly $75 million. While the main reason for this damage and disruption is simple—the tunnel entrance was not flood-proof—it also underscores the broader vulnerability of Boston's transportation infrastructure: Its subway system—the country's oldest—was not built with certain conditions in mind, including significantly higher sea levels and storm surges."[4]

The frequency of summer droughts also could increase. NECIA predicts that global warming could worsen air pollution in the Northeast, especially if GHG emissions are not reduced, creating more days when national air-quality standards cannot be met: "Deteriorating air quality would exacerbate the risk of respiratory, cardiovascular, and other ailments in … Massachusetts, which already has the highest rate of adult asthma in the United States." Higher temperatures means that people in Boston could experience double (30 days) to quadruple (60 days) the number of days each year with temperatures above 90°F, including six-to-24 days each year above 100°F; this could increase the risk of heat stroke among vulnerable populations, such as children and the elderly. However, if global greenhouse gas emissions were reduced, it would be possible to achieve the lower end of these ranges (of the number of 90°F and 100°F days) through the end of this century.[5] Ultimately, reducing GHG emissions can limit rising temperatures and prevent the worst-case effects of climate change.

[2] *Confronting Climate Change in the U.S. Northeast*, p. 15.
[3] *Confronting Climate Change in the U.S. Northeast*, p. 8.
[4] *Confronting Climate Change in the U.S. Northeast*, p. 22.
[5] *Confronting Climate Change in the U.S. Northeast*, p. 93.

1.2 ADDRESSING CLIMATE CHANGE

The Boston Region Metropolitan Planning Organization (MPO) has been gathering information on climate change and its effects in the Boston area since 2007. In May 2008, MPO staff published a discussion paper *Carbon Dioxide, Climate Change, and the Boston Region MPO* to inform the MPO and public about climate change issues. In 2012, staff updated this paper with new information about observed changes in climate, new policies and legislation, and new MPO initiatives that address climate change.

Why use units of "carbon dioxide equivalent"?

Although CO_2 is the primary type of greenhouse gas emitted by the transportation sector, other types of greenhouses gases, such as methane, nitrous oxide, and chlorofluorocarbons also are emitted. These gases have higher "global warming potential" than carbon dioxide, meaning that a ton of methane emitted, for example, contributes 28-to-36 times more to climate change than a ton of carbon dioxide. Even relatively small quantities of these other GHGs are important to take into account. Carbon dioxide equivalents (CO_2e) provide a metric that can include the effect of any GHG by comparing its warming effect to that of CO_2. In this report, any strategy's GHG reduction potential expressed in CO_2e considers not only CO_2 emissions, but also the emissions of other types of GHGs.[11]

Concurrently, the state enacted the Massachusetts Global Warming Solutions Act (GWSA) in 2008 to create a framework for reducing greenhouse gas (GHG) emissions to levels that scientists believe would give us a chance to avoid the worst effects of global climate change, such as stronger storms, severe flooding, drought, heat waves, and disruption to ecosystems and food supplies. The Act requires reductions of GHG emissions of 25 percent from 1990 levels by 2020, and 80 percent from 1990 levels by 2050 from all sectors. Massachusetts GHG emissions in 1990 were approximately 94 million metric tons of carbon dioxide equivalents ($MMTCO_2e$).[6] As shown in Figure 1.1, the GWSA limit for 2020 would require a reduction of 23 $MMTCO_2e$, while the GWSA limit for 2050 would require a reduction of 75 $MMTCO_2e$.[7] See sidebar, "The Value of a Metric Ton of CO_2" for more information. [8]

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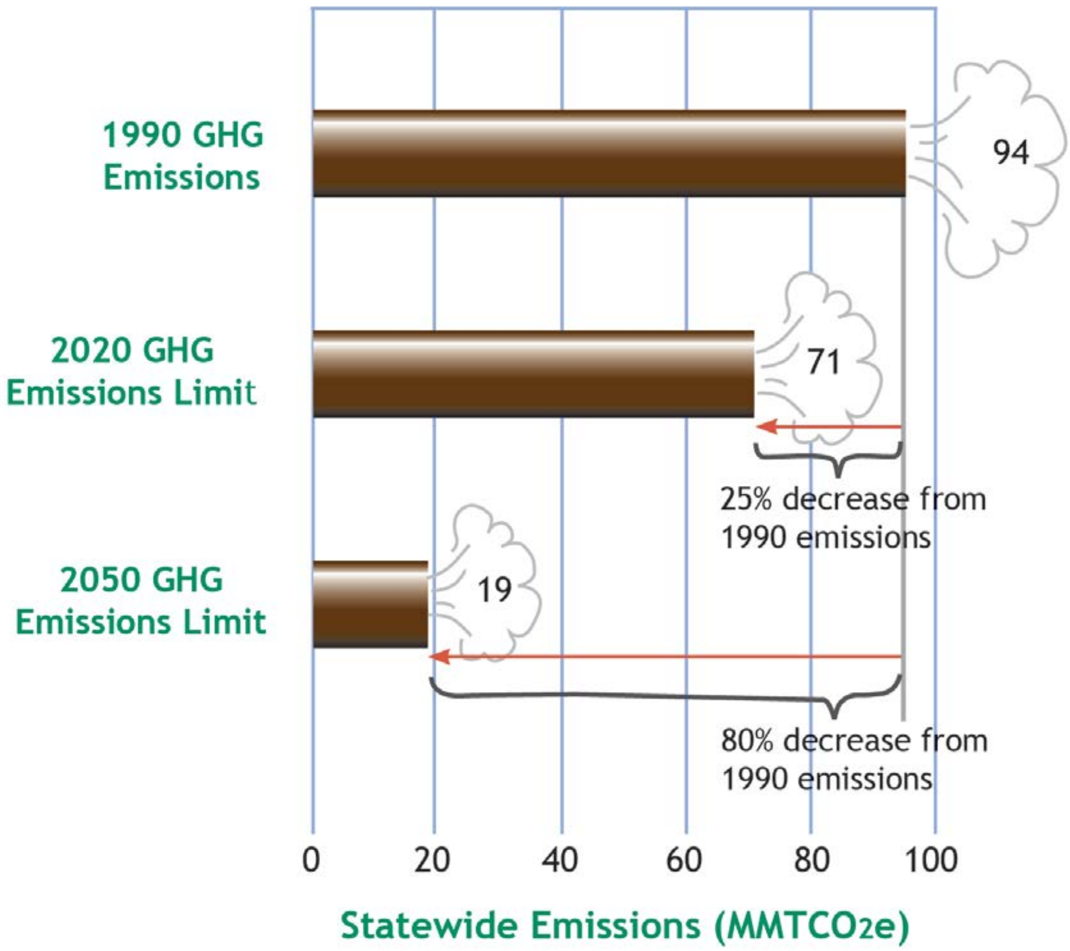
[6] Massachusetts Department of Environmental Protection, Executive Office of Energy and Environmental Affairs, *Statewide Greenhouse Gas Emissions Level: 1990 Baseline and 2020 Business As Usual Projection,* 2009, http://www.mass.gov/eea/docs/dep/air/climate/1990-2020-final.pdf.

[7] Massachusetts Department of Environmental Protection, Executive Office of Energy and Environmental Affairs, *Global Warming Solutions Act 5-Year Progress Report*, 2013, http://www.mass.gov/eea/docs/eea/gwsa/ma-gwsa-5yr-progress-report-1-6-14.pdf.

[8] United States Environmental Protection Agency, GHG Equivalencies Calculator – Calculations and References, 2015, http://www2.epa.gov/energy/ghg-equivalencies-calculator-calculations-and-references.

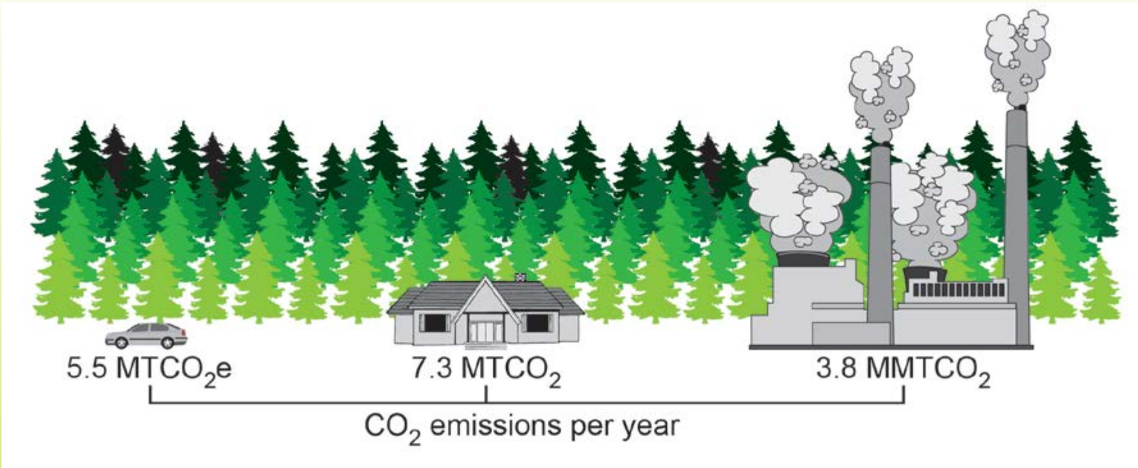
Preliminary findings from the forthcoming update to the Commonwealth's Clean Energy and Climate Plan indicate that a reduction of GHG emissions of approximately 17 percent has been achieved through 2014.

FIGURE 1.1
Massachusetts Statewide GHG Emissions, All Sectors: 1990 Baseline and Global Warming Solutions Act 2020 and 2050 Limits



Source: Massachusetts Department of Environmental Protection, *Global Warming Solutions Act 5-Year Progress Report.*

The Value of a Metric Ton of CO_2



Source: Central Transportation Planning Staff.

The examples above convey a sense of the value of a metric ton of CO_2: A passenger vehicle that is driven 12,000 miles annually emits approximately 5.5 metric tons of CO_2e. Electricity used by the average home produces 7.3 metric tons of CO_2 annually. A coal-fired power plant emits 3.8 million metric tons of CO_2 each year. [8] (Please note that this diagram is not to scale)

With respect to transportation, projections based on data from the US Department of Energy and US Department of Transportation forecast substantial increases in the fuel efficiency of automobiles and light trucks between now and 2050, which will produce valuable gains in GHG reductions. These reductions, however, nearly entirely are counterbalanced by a simultaneous increase in vehicle-miles traveled (VMT) because of increases in the US population and travel. Between 2005 and 2050, a net increase in baseline GHG emissions of less than one percent is projected.[9]

Extrapolating these national trends to Massachusetts and the Boston region, achieving GHG emission reductions to GWSA levels may not be realized based on new vehicle technologies alone; the other transportation strategies discussed in the literature review (in Chapters 3 and 4 of this report) may be needed. In further examining Massachusetts VMT data after 2008, VMT has dropped below 2008 levels and is now increasing, however, at a slower rate than in the past. Further research is needed to understand if this national trend is occurring in Massachusetts.

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[9] Cambridge Systematics, Inc., 2009, *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*, Urban Land Institute, p. 79-83.

To help meet the GWSA requirements, the Massachusetts Department of Transportation (MassDOT) adopted its GreenDOT policy initiative to help reduce GHG emissions by:

- Implementing travel demand management projects
- Promoting healthy transportation modes by improving pedestrian, bicycle, and public transit infrastructure
- Supporting smart-growth development by making transportation investments that enable denser, smart-growth development patterns that can support reduced GHG emissions

The responsibility of the MPO is to prioritize and fund projects, programs, and studies that help to advance its vision, goals, and objectives through its Unified Planning Work Program (UPWP), Transportation Improvement Program (TIP), and Long-Range Transportation Plan (LRTP). The MPO recently adopted its new LRTP, *Charting Progress to 2040*. As part of the LRTP's goals and objectives, the MPO adopted a goal for Clean Air and Clean Communities. One of its objectives is to "reduce greenhouse gases generated in the Boston region by all transportation modes as outlined in the Global Warming Solutions Act."

Currently, the MPO tracks the projected GHG impacts of infrastructure projects. GHG impacts are tracked at the regional level in the LRTP and at the project level in the TIP. Staff also performs a GHG and cost-effectiveness analysis for TIP projects seeking funding under the Congestion Mitigation and Air Quality Improvement Program (CMAQ). The CMAQ program provides funding for a wide range of projects that reduce transportation-related emissions, including carbon dioxide, the major contributor to climate change.

Because reducing GHG emissions is an important goal of the MPO, staff are undertaking this study to identify cost-effective GHG reduction strategies that can help inform MPO investment decisions. Some examples of GHG reduction strategies are projects that improve traffic flow, support fleet upgrades, or shift travelers from single-occupant vehicles to biking, walking, or taking transit.

This report builds on the two previous MPO papers described earlier and explores different cost-effective GHG reduction strategies that the MPO can fund or implement. Chapters 3 and 4 include a literature review and research into work performed by federal, state, and regional transportation agencies; universities; and advocacy and nonprofit organizations that could yield information on the GHG impacts and the costs of implementing various reduction strategies across all transportation modes. In Chapter 5, MPO staff inventoried past and current MPO programming within the context of these strategies and

quantified the projected GHG impacts using various tools. MPO staff calculated the cost-effectiveness of each transportation strategy to identify those strategies that would be most effective at reducing GHG emissions. Finally, Chapter 6 summarizes ongoing work that would further help the MPO to make informed decisions when prioritizing and funding projects, programs, and studies to reduce GHG emissions in the future. It also discusses next steps that the MPO can take to consider GHG as part of its decision-making process.

Chapter 2—The MPO's Role in Greenhouse Gas Reduction

2.1 MPO RESOURCES TO SUPPORT GHG REDUCTION

The optimal greenhouse gas reduction strategies for the Boston Region MPO not only will need to demonstrate cost effectiveness; they also will need to align with the MPO's roles and capabilities. The strategies discussed throughout this report should be considered in light of these roles and capabilities. The MPO has several tools at its disposal to support reductions in the GHG emissions that are produced by the region's transportation system, including the MPO's:

- Capital-investment funds allocated through the LRTP and the TIP
- Planning and research funds, which are described in the UPWP
- Public outreach and involvement tools, which are supported with UPWP funds and can be used to disseminate information
- Potential role as an advocate for various transportation policies and practices

2.1.1 MPO Capital Investment Funds

The MPO receives discretionary federal highway program funding, or Regional Target Funds, annually. This pool of discretionary funds is determined after other statewide transportation funding needs—such as those for Grant Anticipation Note (GANs) payments for the Commonwealth's Accelerated Bridge Program, Statewide Infrastructure Items, and Regional Major Infrastructure Projects—have been satisfied. MassDOT distributes these discretionary funds to the Commonwealth's 13 MPOs by formula. The Boston Region MPO's LRTP describes how the MPO plans to spend its estimated Regional Target Funds over a 25-year time horizon; and the MPO's TIP describes how the MPO would program these funds for specific projects during a 5-year period.

This discretionary federal highway program funding supports:

- Preservation and modernization of existing roadway network through resurfacing highways
- Replacement of bridges
- Reconstruction of arterial roadways
- Intersection improvements
- Off-road bicycle and pedestrian improvements

In addition, program funding may be expended on transportation projects that will improve air quality, and may be "flexed" for use on transit projects. (While the LRTP and TIP describe how Federal Transit Administration (FTA)-provided transit capital investment funds will be used in the Boston Region, the MPO can program transit projects only by using these "flexed" highway funds.)

The MPO's vision, goals, and objectives, as described in *Charting Progress to 2040*—create the framework that determines how the MPO will spend these discretionary funds. Using this framework, the MPO has established a series of investment programs. Several of the programs—including Intersection Improvements, Complete Streets, Bicycle Network and Pedestrian Connections, Community Transportation and Parking, and transit projects included in the Major Infrastructure category—relate directly to the MPO's Clean Air/Clean Communities goal. These investment programs will be supported by a series of federally designated funding programs, which are described in Table 2.1 below.

TABLE 2.1
Federal Funding Programs

Program Name	Program Description	Examples of Eligible Projects with Potential GHG Reduction Impacts [a]	Flex Funds to Transit?	Relevant MPO Investment Programs
Congestion Mitigation and Air Quality Improvement (CMAQ)	Wide range of projects in air quality nonattainment and maintenance areas for ozone, carbon monoxide, and particulate matter, that reduce transportation-related emissions	• Transit investments • Projects or programs that increase vehicle occupancy, shift travel demand to non-peak hours; or reduce travel demand (such as tele-working) • Projects or programs that improve travel flow • Non-recreational bicycle and pedestrian improvements • Public education campaigns • Alternative fuel projects (e.g., vehicle acquisitions, engine retrofits)	Yes (Includes funding for capital improvement, vehicle procurement and as many as three years' operations assistance)	• Complete Streets • Intersection Improvements • Major Infrastructure Projects (including Highway Funds Flexed to Transit) • Community Transportation • Bicycle/Pedestrian Program
Surface Transportation Block Grant Program (STBGP)	Broad range of surface transportation capital needs, including roads; transit, sea, and airport access; and vanpool, bicycle, and pedestrian facilities	• Congestion pricing projects and strategies • Construction, reconstruction, rehabilitation, resurfacing, restoration, preservation, or operational improvements for highways • Capital and operating costs for traffic monitoring, management and control facilities and programs, including advanced truck stop electrification • Carpool projects, fringe and corridor parking facilities and programs, including electric and natural gas vehicle charging infrastructure, bicycle transportation and pedestrian walkways, and accessible sidewalk modification • Transit capital costs	Yes, e.g., Green Line Extension Project (Phase 2), College Avenue to Mystic Valley Parkway/Route 16)	• Complete Streets • Intersection Improvements • Major Infrastructure Projects (including Highway Funds Flexed to Transit) • Community Transportation • Bicycle/Pedestrian Program
Highway Safety Improvement Program (HSIP)	Implementation of infrastructure-related highway safety improvements	• Traffic controls and warning devices • Intersection safety improvements • Railway-highway crossing safety features • Safety improvements for bicyclists, pedestrians, and other forms of non-motorized transportation	No	• Complete Streets • Intersection Improvements • Major Infrastructure Projects

Program Name	Program Description	Examples of Eligible Projects with Potential GHG Reduction Impacts [a]	Flex Funds to Transit?	Relevant MPO Investment Programs
National Highway Performance Program (NHPP)	Improvements to interstate routes, major urban and rural arterials, connectors to major intermodal facilities, and the national defense network. Also includes replacing or rehabilitating any public bridge, and resurfacing, restoring, and rehabilitating routes on the Interstate Highway System	• Construction, reconstruction, resurfacing, restoration, rehabilitation, preservation, or operational improvements of national highway system (NHS) segments • Construction of publicly owned intra- or inter-city bus terminals servicing the National Highway System • Bicycle transportation and pedestrian walkways	Yes	• Major Infrastructure Projects
Discretionary Funding	Specific projects included annual appropriations that are funded through grant programs such as the Transportation, Community, and System Preservation Program; Value Pricing Pilot Program; and Transportation Infrastructure Finance and Innovation Act Program.	• Dependent on specific project or program	Dependent on specific project or program	

Additional eligible projects information may be found at:
CMAQ – http://www.fhwa.dot.gov/map21/guidance/guidecmaq.cfm
HSIP – http://safety.fhwa.dot.gov/hsip/resources/fhwasa09029/sec5.cfm
NHPP – http://www.fhwa.dot.gov/map21/factsheets/nhpp.cfm
STP – http://www.fhwa.dot.gov/map21/factsheets/stp.cfm
TAP – http://www.fhwa.dot.gov/map21/guidance/guidetap.cfm
Source: Central Transportation Planning Staff.

2.1.2 MPO Planning Funds

MPOs receive metropolitan planning funds from the Federal Highway Administration (FHWA) and the FTA in order to provide for a continuing, comprehensive, and cooperative (3-C) transportation planning process in their regions. Like the MPO's capital investment funds, these funds are distributed by MassDOT to the Commonwealth's 13 MPO regions. In the Boston Region, the Central Transportation Planning Staff (CTPS) receives approximately 80 percent of these funds, while the Metropolitan Area Planning Council (MAPC) receives the other 20 percent. The MPO's plan for expending these funds is documented in the UPWP.

The Boston Region MPO uses these metropolitan transportation-planning funds to satisfy 3C planning process requirements, including, but not limited to

1. Developing the LRTP, TIP and UPWP
2. Supporting public participation in the transportation planning process
3. Conducting performance-based planning
4. Ensuring conformity with air quality requirements

MPOs also use these funds to conduct corridor, safety, and other planning studies; collecting data; monitoring trends; and studying a variety of demographic, land use development, transportation, and environmental factors. CTPS and MAPC use these planning funds to provide technical assistance to municipalities, transportation agencies, and other organizations, as well as to conduct independent studies. Through data requests, the funding can support research at local universities to understand the impacts of GHG emissions and climate change. While these funds must be used for planning activities that relate to the region's transportation system, they are flexible and may be used as tools for finding ways to reduce transportation-related GHG emissions. For example, these funds may support feasibility studies of new bicycle and pedestrian connections, transit services, travel demand management (TDM) strategies or other GHG-emission-reduction policies.

2.1.3 MPO Public Outreach and Involvement Tools

The MPO maintains various lines of communication to keep interested parties informed about and involved in the Boston region's metropolitan transportation-planning process, including:

- MPO and MPO committee meetings, Regional Transportation Advisory Council meetings, and MPO-sponsored events
- Online resources, including the MPO's website, Twitter feed, and email distribution list (MPO info)
- The MPO's bimonthly newsletter, *TRANSreport*

While these channels are used primarily for MPO business, they also could be used to communicate educational information about ways that travelers can reduce transportation-related greenhouse gas emissions. They also can announce the availability of transportation programs, projects, and resources—whether MPO funded or not—that may reduce greenhouse gas emissions.

In some cases, information and education campaigns pertaining to the connections between transportation choices, congestion, and air quality can be supported using CMAQ funds.

2.1.4 MPO Advocacy and Partnerships

If an existing or potential greenhouse gas reduction policy, program, or project falls outside of the MPO's purview, the MPO may choose to advocate on behalf of such a policy to the relevant body, such as MassDOT, the Massachusetts Bay Transportation Authority (MBTA), the Commonwealth's State Legislature or Governor, federal agencies, or national organizations.

Chapter 3—Literature Review

3.1 LITERATURE RELEVANT TO THIS STUDY

As awareness of the dangers posed by climate change widens, numerous studies have examined different strategies to reduce greenhouse gas emissions. Staff reviewed a number of these reports and found that those comparing strategies that use the same criteria offered the most applicable information. These studies include:

- *Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process*, a Transportation Research Board (TRB) of the National Academies, Strategic Highway Research Program (SHRP2) study, by PB Americas, Inc., Cambridge Systematics, Inc., E. H. Pechan & Associates, Inc., and EuQuant, Inc., Report S2-C09-RR-1 (Washington, D.C.), 2013
- *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*, an Urban Land Institute (Washington, D.C.) study, by Cambridge Systematics, 2009
- *Transportation's Role in Role in Reducing U.S. Greenhouse Gas Emissions*, a U.S. Department of Transportation (Washington, D.C.) report to Congress, by Cambridge Systematics, Inc. and Eastern Research Group, Inc., 2010
- *Reference Sourcebook for Reducing Greenhouse Gas Emissions from Transportation Sources*, US Department of Transportation, Federal Highway Administration, by Rand Corporation and RSG Inc., 2012

In addition, *Reducing Greenhouse Gas Emissions from Transportation, Opportunities in the Northeast and the Mid-Atlantic,* was released in November 2015, by the Georgetown Climate Change Center as part of the Transportation Climate Initiative (TCI). The TCI, of which Massachusetts is a member, is a collaboration of 12 Northeast and Mid-Atlantic jurisdictions committed to working together to develop a clean-energy economy and reduce greenhouse gas emissions in the transportation sector. Cambridge Systematics, an author of *Moving Cooler,* contributed the quantitative aspects of the report. It is also important to note that the Massachusetts Executive Office of Energy and Environmental Affairs is in the process of updating its Clean Energy and Climate Plan for 2020. The revised information will be available upon its release.

Greenhouse gas-reducing strategies for the transportation sector may be divided into eight categories, as follows:

1. Transportation System Planning, Funding and Design
2. Construction and Maintenance Practices
3. Transportation System Management and Operations
4. Land Use Codes, Regulations, and Policies
5. Taxation and Pricing
6. Travel Demand Management
7. Public Education
8. Vehicle and Fuel Improvements

Table 3.1 below lists the eight categories of strategies that were identified in this literature review. It also cites briefly the results of the literature review discussions. For example, strategies that show promise for reducing GHG emissions are discussed in Section 3.3 of this report, while strategies that may have a questionable impact on GHGs are discussed in Section 3.5. The GHG reduction potential of Vehicle and Fuel Improvements strategies—low carbon fuels, advanced-vehicle technologies, and vehicle air-conditioning systems—are not covered in this literature review. These three strategies already are factored into the GHG baselines in various reports.[10] The MPO does not have the authority to implement or ability to influence these strategies.

TABLE 3.1
Types of GHG Reduction Strategies with Literature Review Classification

Category	Identified Strategy	Literature Review Discussion Results
Transportation System Planning, Funding, and Design	Expansion of urban fixed-guideway transit	Promising strategy
	Pedestrian improvements	Promising strategy
	Bicycle improvements	Promising strategy
	Rail freight infrastructure	Promising strategy
	National top 100-to-200 bottleneck relief	Questionable strategy
	Capacity expansion	Questionable strategy
Construction and Maintenance Practices	Alternative construction materials	Promising strategy
Transportation System Management and Operations	Transit fare reductions	Promising strategy

[10] Cambridge Systematics, 2009, *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*, Urban Land Institute, Washington, D.C., p. 19.

Category	Identified Strategy	Literature Review Discussion Results
	Increased transit service	Promising strategy
	Truck idling reduction	Promising strategy
	Reduced speed limits	Promising strategy
	Traffic management	Questionable strategy
	Ramp metering	Questionable strategy
Land Use Codes, Regulations, and Policies	Compact development	Promising strategy
	Parking management	Promising strategy
Taxation and Pricing	Carbon tax or cap-and-trade	Promising strategy
	Pay-as-you-drive insurance	Promising strategy
	Vehicle miles traveled fees	Promising strategy
	Congestion pricing	Promising strategy
Travel Demand Management	Workplace travel demand management (TDM) (general)	Promising strategy
	Teleworking	Promising strategy
	Compressed work weeks	Promising strategy
	Individualized marketing	Promising strategy
	Ridesharing	Promising strategy
	Car sharing	Promising strategy
Other Public Education	Driver education/eco-driving	Promising strategy
	Information on vehicle purchase	Promising strategy
Vehicle and Fuel Improvements	Advanced-vehicle technologies	Factored into GHG baselines
	Vehicle air-conditioning systems	Factored into GHG baselines
	Low carbon fuels	Factored into GHG baselines

Note: Strategies that show promise for reducing GHG emissions are discussed in Section 3.3 of this report. Strategies that may have a questionable impact on GHGs are discussed in Section 3.5.

Sources: Cambridge Systematics, Moving Cooler and Transportation Research Board, Incorporating Greenhouse Gas Emissions.

3.2 STRATEGY SELECTION CRITERIA

Staff used three main criteria to evaluate identified GHG emissions-reduction strategies:

- Greatest potential to reduce greenhouse gas emissions (assuming maximum level of deployment and successful implementation)
- Cost-effectiveness in terms of direct implementation costs
- Other considerations, including equity and social benefits or concerns, implementation feasibility, and potential MPO roles

3.2.1 Strategies' Potential to Reduce GHG Emissions

3.2.1.1 Quantifying the Strategies' Potential

For this literature review, a strategy's potential to reduce greenhouse gas emissions is quantified by percentage of reduction in transportation sector greenhouse gas emissions in 2030. This year was chosen because the primary source of this information was the Transportation Research Board report *Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process*, which examined the potential of various strategies to reduce GHG emissions compared to a 2030 baseline. Emissions impacts in 2050 are discussed in some cases where they greatly differ from 2030 impacts. The percentages provided are based a national level of implementation, since state- and region-specific data are not widely available. On occasion, GHG reductions are expressed in terms of million metric tons carbon dioxide equivalent ($MMTCO_2e$) in addition to percentages.[11]

Staff selected the strategies listed because they have a maximum potential to reduce national transportation GHG emissions of at least 0.2 percent compared to the 2030 baseline. Additional GHG reduction strategies exist, but they were excluded from this literature review if they do not have a maximum potential to reduce national emissions of at least 0.2 percent. A strategy's potential is considered "high" if it can reduce GHG by a maximum of at least one percent; "low" if it can reduce GHG by less than one-half percent; and "medium" if it can reduce GHG between one and one-half percent.

Although national emissions data were used in this report because of lack of state- or region-specific data for the strategies, we caution that the relative reductions that a strategy can achieve at the national level may be significantly different at state and regional levels. For instance, strategies such as bicycle and pedestrian improvements may yield the greatest emissions reductions in areas with relatively greater land use density, where trips between origins and destinations are relatively short. Because Massachusetts and the Boston region have greater population and employment densities than the rest of the country, bicycle and pedestrian improvements may be able to achieve relatively high

[11] US Environmental Protection Agency, 2015, *Understanding Global Warming Potentials*, http://www3.epa.gov/climatechange/ghgemissions/gwps.html.

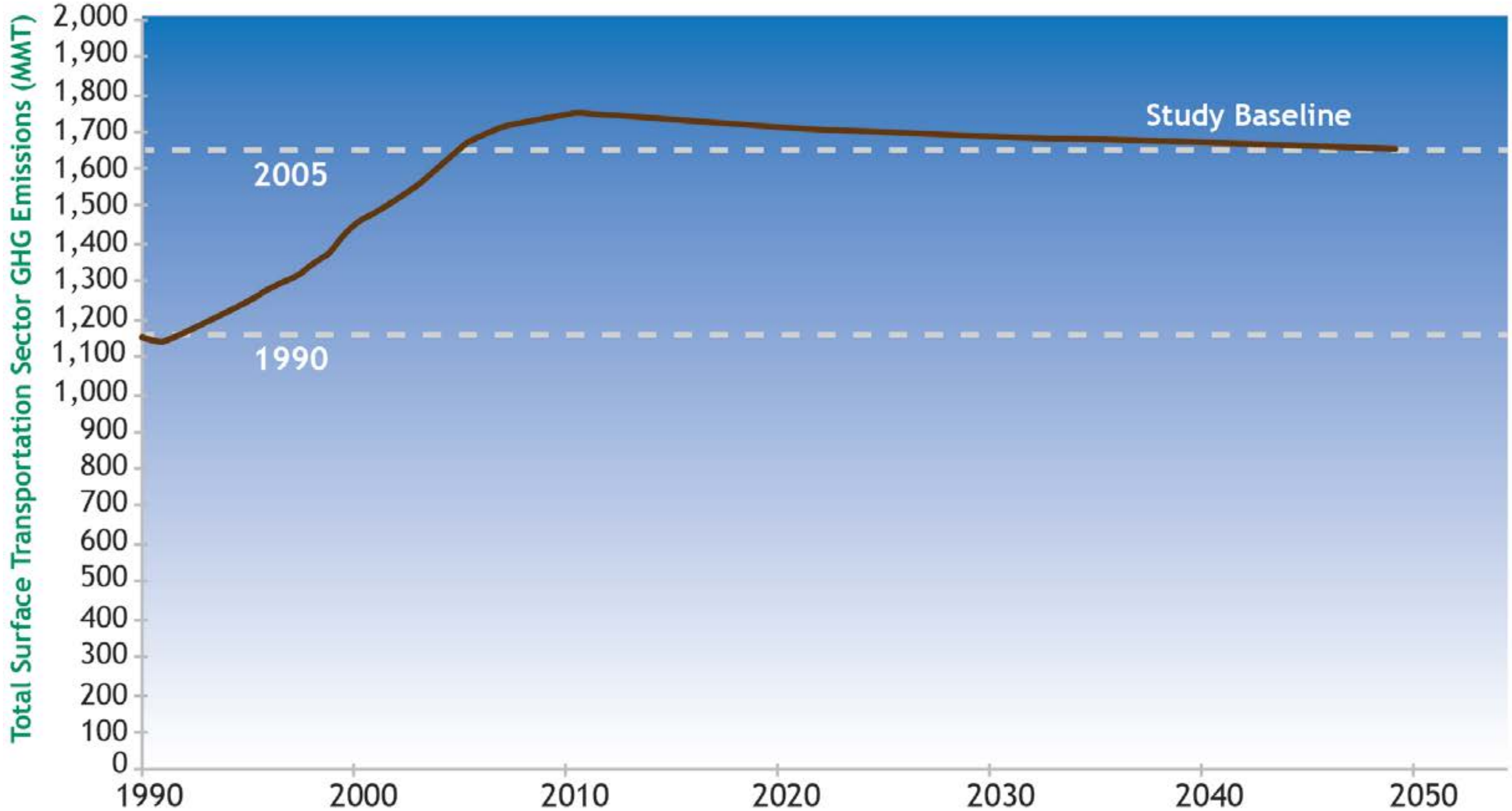
GHG emissions reductions compared to the country as a whole. Congestion pricing is another example of a strategy that may have a relatively higher impact on GHG emissions in the Boston region than the nation as a whole, as it can be implemented only in certain congested locations. *Moving Cooler* states: “Of course, in the context of the regions in which congestion pricing is implemented (versus this study’s national perspective), the relative impact on GHGs will be greater.”[12] In order to understand fully the effects of implementing GHG reduction strategies in the Boston region, studies are needed to develop region-specific data for each strategy. In the meantime, national data is the best information available.

The *Moving Cooler* report cited above provides a context for national transportation emissions levels over time, which may be considered in light of GWSA limits for emissions reductions below 1990 levels.

The national transportation GHG emissions 1990 baseline was about 1,150 $MMTCO_2e$. Between 1990 and 2005, the baseline for the national transportation sector increased roughly 40 percent to about 1,650 $MMTCO_2e$. Looking forward, between 2005 and 2050 the baseline remains largely the same. *Moving Cooler* projects a net increase in baseline GHG emissions between 2005 and 2050 of less than one percent (including predicted increases in both VMT and fuel efficiency), with emissions declining from their peak in 2010. The difference between the 2005 and 2030 baseline is about three percent.[13] In order to reduce GHG emissions to GWSA targets below 1990 levels, the increases that took place between 1990 and 2005 need to be cut, in addition to the target cuts from 1990 levels. Figure 3.1 below shows the national emissions baseline for 1990, 2005, and beyond.

[12] Cambridge Systematics Inc., *Moving Cooler*, p. 40.
[13] Cambridge Systematics, *Moving Cooler*, pp. 79-83.

FIGURE 3.1
National Transportation GHG Baseline: 1990, 2005, and Beyond



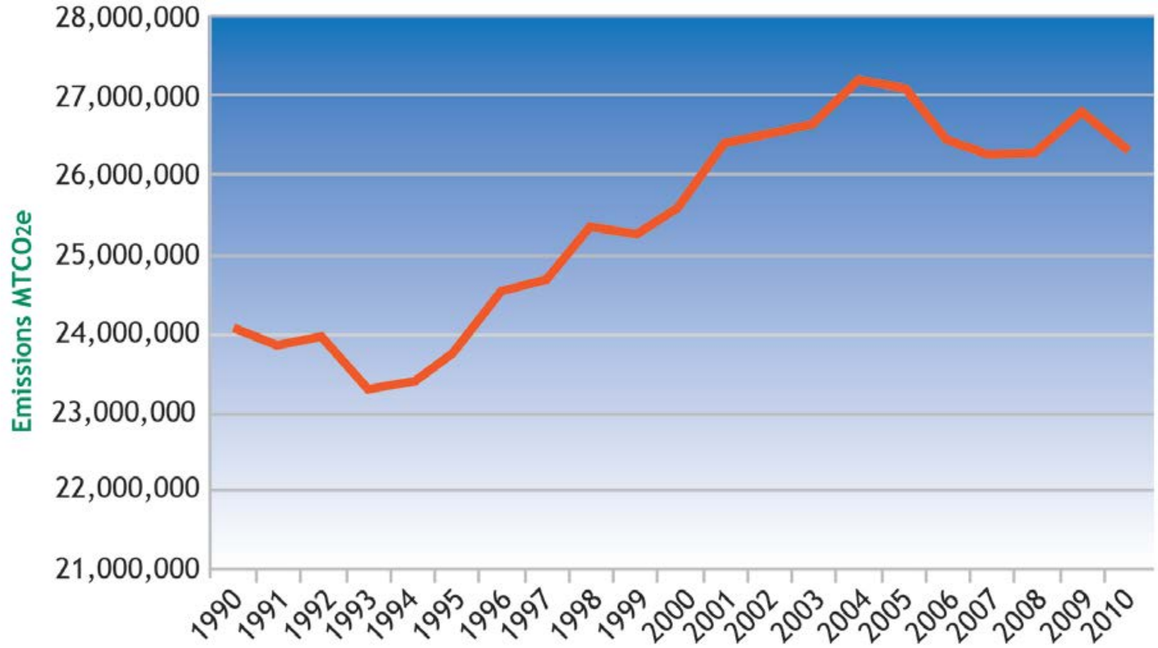
1990 and 2005 GHG Emissions - Combination of DOA AEO data and EPA GHG Inventory data
Study Baseline - Annual 1.4 percent VMT growth combined with 1.9 percent growth in fuel economy

AEO = Annual Energy Outlook. DOE = Department of Energy. VMT = vehicle miles traveled.
Source: Cambridge Systematics, *Moving Cooler.*

In Massachusetts the emissions baseline increased less between 1990 and 2005 when compared to the national level, so Massachusetts has proportionally less emissions to cut to get to below 1990 levels. Figure 3.2 below, shows GHG emissions from surface transportation in Massachusetts between 1990 and 2010. The figure indicates that greenhouse gas emissions from surface transportation in Massachusetts increased about 13 percent between 1990 and 2005, a smaller increase than the roughly 40 percent increase in GHG emissions at the national level.[14]

In Figure 3.2, emissions appear to stay the same or decrease between 2005 and 2010. While no business-as-usual baseline has been projected yet for the Massachusetts transportation sector through 2030, data through 2012 show Massachusetts emissions have remained at 2005 levels thus far.

FIGURE 3.2
Massachusetts Surface Transportation GHG Emissions, 1990–2010

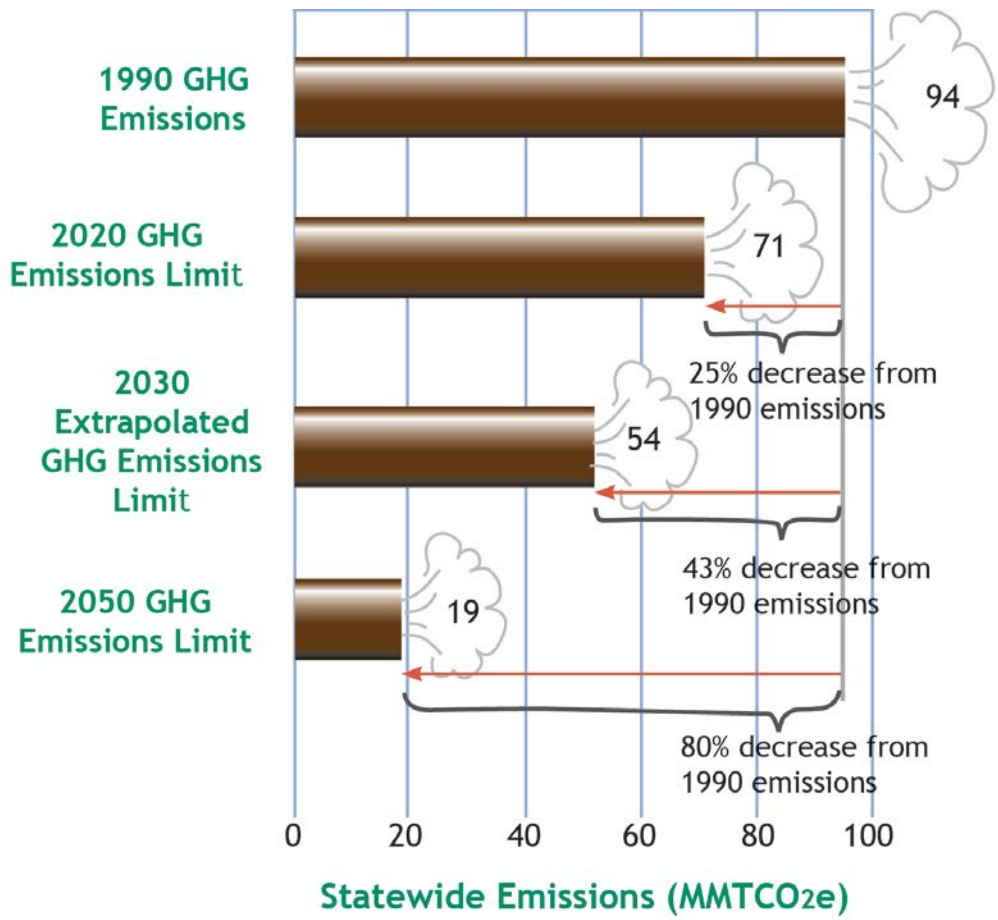


Source: *Global Warming Solutions Act 5-Year Progress Report.*

[14] Massachusetts Executive Office of Energy and Environmental Affairs, *Global Warming Solutions Act 5-Year Progress Report*, 2013, http://www.mass.gov/eea/docs/eea/gwsa/ma-gwsa-5yr-progress-report-1-6-14.pdf.

Staff evaluated these strategies in terms of the potential percentage of emissions reductions from the current national 2005–2050 baseline by 2030, rather than by 2020 or 2050, so some extrapolation is needed to compare the 2030 data with the Massachusetts statewide GWSA limits for this year. Figure 3.3 below shows that a 43 percent decrease from 1990 levels in all sectors would be needed to reach a theoretical 2030 goal linearly set between the 2020 and 2050 limits.

FIGURE 3.3
Massachusetts Statewide GHG Baseline and GWSA Limits, All Sectors



Source: Massachusetts Department of Environmental Protection, *Global Warming Solutions Act 5-Year Progress Report.*

3.2.1.2 Combining Strategies

In order to reduce GHG emissions significantly, it would be necessary to utilize multiple strategies. For example, it would take 77 strategies each with a maximum reduction potential of 0.6 percent from the baseline by 2030 to match the maximum GHG reduction potential of a cap-and-trade or carbon tax initiative (defined in chapter four), a 4.6 percent reduction in 2030. Fourteen of the 24

strategies studied in this literature review each have a maximum GHG reduction potential of 0.6 percent or less. It may be possible to achieve greater emissions reductions when combining multiple strategies, especially when a strategy with a low emissions-reduction potential is paired with one with a higher potential.

Notably, the GHG reduction potential of individual strategies cannot simply be added together to estimate the cumulative effect. As the following *Moving Cooler* example shows, the combined effects of each strategy must be multiplied, which results in a slightly smaller cumulative reduction.

> For example, imagine that implementing strategy “A” results in a 10 percent reduction [in GHG emissions] from the study baseline. Implementing strategy “B” on its own would also result in a 10 percent reduction. However if strategy “B” is implemented in addition to strategy “A”, it will reduce 10 percent of the 90 percent [emissions] remaining, or 9 percent. That is, the combined effect will be 0.90 x 0.90 = 0.81, or a 19 percent combined reduction, rather than the 20 percent that would occur if the reductions were simply added.

The difference between multiplying the effects and just adding the reductions will be greater as the number of individual strategies being combined increases.[15]

Furthermore, the different strategies interact with each other, some with synergistic effects and others with opposing effects. Strategies that work together synergistically can result in GHG reductions larger than the sum of the reductions of the individual strategies. Compact development (defined in Chapter 4) in particular plays a well-studied, significant role in supporting walking, biking, car-sharing, and urban public transportation.[16] More information on this topic is available in Section 3.3.

3.2.1.3 Strategy Deployment

The level at which a strategy is deployed—expanded, aggressive, or maximum—is crucial in determining how large a GHG reduction can be achieved. The implementation of a strategy is associated with a range in GHG reductions; the high end of this range may be very promising, while the low end could be as low as no emissions reduction at all. This range reflects the variability in deployment levels. Aggressive or maximum levels of deployment of transportation demand

[15] Cambridge Systematics, *Moving Cooler*, p. 35.
[16] Cambridge Systematics, *Moving Cooler*, p. 35-36.

management and transportation system management strategies will be needed to reach GHG reduction limits in the Global Warming Solutions Act.

According to *Moving Cooler*, three key factors comprise the level of deployment[17]:

1. Geography: Refers to how broadly a strategy is implemented across a region, from large urban areas only to all areas including rural areas.
2. Time frame: Signifies how quickly a strategy is put into effect; since GHG emissions are cumulative, earlier cuts in emissions can provide the greatest overall impact over time and could help with meeting the first GWSA limit for 2020. Alternatively, if the implementation of a strategy is delayed, it will not have as much time to take effect by 2020 or 2030, potentially with smaller GHG reductions achieved by those dates.
3. Intensity: Describes the magnitude of implementation. For example, the difference between installing bike lanes and paths at one-mile intervals in urban areas and installing them at one-quarter-mile intervals is a difference in intensity.

Together, geography, time frame, and intensity make the difference between aggressive and maximum deployment, and in turn determine the quantity of greenhouse gas emissions that are prevented from entering the atmosphere.

3.2.2 Strategy Cost-Effectiveness

Each strategy's cost-effectiveness is quantified in terms of the direct cost to the implementing agency per $MTCO_2e$ reduced. This report discusses cost-effectiveness based on a national level of implementation. A strategy's cost or savings to the public also are provided when available, because many strategies have been found to save the public money.

For the purpose of comparison, staff divided strategies into "high," "medium," and "low" cost-effectiveness. Strategies were considered to have high cost-effectiveness if they cost less than $250 per $MTCO_2e$ reduced; low cost-effectiveness if they cost more than $500 per $MTCO_2e$ reduced; and medium cost-effectiveness if their costs fall in the middle of this range. These categories were informed by the *Incorporating Greenhouse Gas Emissions* report by the Transportation Research Board, which quantifies direct implementation costs.[18]

[17] Cambridge Systematics, *Moving Cooler*, p. 82.
[18] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 33.

There is also uncertainty surrounding the cost-effectiveness estimates of many strategies because of limited studies on cost-effectiveness. Furthermore, the cost-effectiveness of an approach can differ considerably by location (e.g., rural versus urban), as well as context. The Transportation Research Board cautions against drawing blanket conclusions.[19] It recommends that strategies with substantial GHG reduction potential not be ruled out on the basis of cost without analyzing the local region specifically, and considering them as part of a larger set of strategies, some of which (e.g., pricing strategies) can provide revenue to support other more costly strategies.

We summarize the categories for measuring GHG reduction potential and cost-effectiveness in Table 3.2 below.

TABLE 3.2
Greenhouse Gas Reduction Potential and Cost-Effectiveness Categories

Category	Greenhouse Gas Reduction Potential	Cost-Effectiveness
High	One percent or more reduction compared to 2030 baseline	Less than \$250 per $MTCO_2e$
Medium	Between 0.5 and 1 percent compared to 2030 baseline	Between \$250 and \$500 $MTCO_2e$
Low	Less than 0.5 percent compared to 2030 baseline	More than \$500 per $MTCO_2e$

$MTCO_2e$ = metric tons carbon dioxide equivalent.
Source: Transportation Research Board*, Incorporating Greenhouse Gas Emissions.*

3.2.3 Other Strategy Considerations

In addition to cost- and emission-effectiveness, many other considerations are important when selecting strategies for implementation. While we discuss cost-effectiveness primarily in terms of direct implementation costs, the Transportation Research Board, and Cambridge Systematics, caution against neglecting other perspectives and inaccurately representing the full social costs and benefits,[20] examples of which include

- Travel time savings
- Other welfare gains or losses (because of accessibility and increased or decreased convenience)
- Equity (incidence of costs and benefits across population groups)

[19] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 33.
[20] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 32-33.

Resources such as *Moving Cooler* and *Transportation's Role* (Cambridge Systematics and Eastern Research Group) quantify net costs (e.g., including vehicle operating savings) when discussing cost-effectiveness, which demonstrates the prevalence of this methodology. However, they both highlight the need to consider further social costs and benefits. For example, while transit expansion and other major infrastructure improvements are not directly cost-effective, they can be worthwhile for additional purposes such as mobility, safety, and livability. They also can support a package of strategies that is collectively more cost-effective, such as when transit is paired with compact development.[21]

This report discusses additional considerations pertaining to each strategy, (where information is available), which include:

- Costs and Benefits:
    - Equity impacts
    - Social concerns
    - Unique strategy benefits
    - Unique negative effects of the strategy
- Feasibility and Timing:
    - Feasibility
    - Implementation concerns
    - Timing of benefits
- Data Needs
- MPO Role

Equity impacts can vary from strategy to strategy. Disproportionate impacts—such as those that result from pricing—on particular groups may need to be balanced or addressed. For example, lower-income groups already spend as much as four times more of their income on transportation compared to higher income groups.[22] Social concerns, highlighted in FHWA's *Reference Sourcebook for Reducing Greenhouse Gas Emissions from Transportation Sources*, consider a public perception of strategies. Unique benefits and unique negative effects include impacts on livability, safety, and the environment.

Implementation feasibility rankings for technical, institutional, and political factors are suggested in the Transportation Research Board's 2013 report, *Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process*. These ratings refer to the feasibility of implementation on a national scale, and may differ for Massachusetts or the Boston region. Implementation concerns may include the need for inter-agency coordination.

[21] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 33.
[22] Cambridge Systematics, *Moving Cooler*, p. 83.

The US Department of Transportation's Report to Congress, titled *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions,* was a central reference for information on timing of benefits (short, medium, or long), as well as other details. Finally, some strategies may be more directly applicable to the MPO's sphere of influence than others, and we account for this factor the descriptions of individual strategies.

3.3 DATA NEEDS

All the strategies discussed in this literature review could benefit from further research. Data on what implementation of each strategy can achieve in Massachusetts and in the Boston Region could better inform decision-making. Some strategies may be able to reduce GHG emissions in Massachusetts or the Boston Region further below a 2030 baseline than they may reduce national emissions below the national 2030 baseline.

Chapter 4—Promising Strategies for Reducing GHG Emissions Identified in Literature Review

4.1 IDENTIFIED PROMISING STRATEGIES

Strategies that were identified as being promising in terms of their ability to reduce GHG emissions include the following, starting with the most effective. In addition to GHG reduction, the strategies may address other MPO goals, as established in in its long-range transportation plan. The goals addressed by each strategy are denoted as follows:

- Safety
- System Preservation
- Capacity Management/Mobility
- Clean Air and Clean Communities
- Transportation Equity
- Economic Vitality

1. **Carbon taxes and cap-and-trade:** A carbon tax "would raise the price of fossil fuels, with more taxes collected on fuels that generate more emissions."[23] Under a cap-and-trade program, the government sets a cap on the level of emissions, and creates allowances for emissions up to the level of the cap. Entities that are sources of carbon emissions can buy or sell these allowances. **Potential to reduce GHG emissions nationally by 2.8 to 4.6 percent from the 2030 baseline.**

2. **Driver education/eco-driving:** Eco-driving refers to smarter and more energy-efficient driving, such as accelerating and braking smoothly. Eco-driving practices can be encouraged through educational campaigns and via "dynamic eco-driving" where technology provides real-time efficiency feedback. **Potential to reduce GHG emissions nationally by 0.8 to 3.7 percent from the 2030 baseline.**

3. **Pay-as-you-drive insurance:** Under a pay-as-you-drive insurance system, drivers are charged for vehicle insurance based on their vehicle-miles-traveled. **Potential to reduce GHG emissions nationally by 1.1 to 3.5 percent from the 2030 baseline.**

[23] http://www.nytimes.com/2015/06/07/opinion/the-case-for-a-carbon-tax.html.

4. **Compact Development:** Compact development can reduce the need for travel because destinations and activities are in close proximity to one another. **Potential to reduce GHG emissions nationally by 0.2 to 3.5 percent from the 2030 baseline.**

5. **Required Employer-Offered Compressed Work Weeks:** Compressed work weeks save greenhouse gas emissions by reducing the number of days that employees need to commute to their workplaces, thus the total amount of vehicle-miles-traveled each week. This assumes that employees would make other non-work related trips during that time, but only using a fraction of the VMT for a typical workday. Compressed-work-week policies could make the choice of a compressed work week either voluntary or mandatory for employees. **Potential to reduce GHG emissions nationally by 0.1 to 2.4 percent from the 2030 baseline, depending on the policy approach taken.**

6. **Vehicle-Miles-Traveled Fees**: These are distance-based fees levied on a driver for using a roadway system. As opposed to tolls, which are facility specific and not necessarily levied strictly on a per-mile basis, these fees are based on the distance driven on a defined network of roadways.[24] **Potential to reduce GHG emissions nationally by 0.8 to 2.3 percent from the 2030 baseline.**

7. **Reduced Speed Limits:** Because vehicles rapidly lose fuel economy as they increase speeds above 50 mph, setting this at the maximum speed prevents wasted fuel by helping drivers achieve maximum efficiency.[25] **Potential to reduce GHG emissions nationally by 1.2 to 2.0 percent from the 2030 baseline.**

8. **Congestion Pricing:** This concept involves charging for travel during peak periods on in certain locations. Some drivers may choose to bypass congestion by using priced lanes, particularly when they are in a hurry and value the time savings. In other cases, people may choose not to travel in certain locations or at certain times to avoid congestion-pricing. **Potential to reduce GHG emissions nationally by 0.5 to 1.6 percent from the 2030 baseline.**

[24] U.S. Department of Transportation, Federal Highway Administration, Road Pricing Defined, http://www.fhwa.dot.gov/ipd/revenue/road_pricing/defined/vmt.aspx.
[25] U.S. Department of Energy, www.fueleconomy.gov, Driving More Efficiently, http://www.fueleconomy.gov/feg/driveHabits.jsp (accessed March 17, 2015).

9. **Alternative Road Construction Materials.** State and local highway departments and other transportation agencies can utilize less energy-intensive materials in highway construction projects to cut their greenhouse gas emissions.[26] **Potential to reduce GHG emissions nationally by 0.7 to 0.8 percent from the 2030 baseline.**

10. **Expansion of Fixed-Guideway Transit:** In the Boston region, this would entail extending the MBTA's existing rapid transit subway lines or adding new rail or bus rapid transit lines. **Potential to reduce GHG emissions nationally by 0.17 to 0.65 percent from the 2030 baseline.**

11. **Teleworking:** Teleworking, or telecommuting, occurs when employees conduct their workday(s) at home or otherwise outside their employer's office, using telecommunications and computer technology to bridge the distance. **Potential to reduce GHG emissions nationally by 0.5 to 0.6 percent from the 2030 baseline.**

12. **Increased Transit Service:** Improvements, such as reduced transit headways, could increase ridership and could decrease the use of single-occupant vehicles by shifting travel from the automobile to transit modes. **Potential to reduce GHG emissions nationally by 0.2 to 0.6 percent from the 2030 baseline.**

13. **Workplace Transportation Demand Management (TDM) (General):** TDM refers to strategies that increase system efficiency by encouraging a shift from single-occupant vehicle (SOV) trips to non-SOV modes (such as carpools or public transit), or shifting auto trips out of peak periods.[27] Workplace TDM can take the form of requirements for employers to reduce SOV trips or conduct informational and encouragement TDM strategy programs. **Potential to reduce GHG emissions nationally by 0.1 to 0.6 percent from the 2030 baseline.**

[26] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 4-6.

[27] http://www.seattle.gov/transportation/docs/ump/07%20SEATTLE%20Best%20Practices%20in%20Transportation%20Demand%20Management.pdf.

14. **Pedestrian improvements:** These include adding or improving sidewalks, crosswalks, crossing signals, shared-use paths, and other facilities, which would support non-motorized travel. **Potential to reduce GHG emissions nationally by 0.10 to 0.31 percent from the 2030 baseline.**

15. **Transit Fare Reductions:** Reduced fares could potentially increase ridership and could decrease the use of single-occupant vehicles. **Potential to reduce GHG emissions nationally by 0.09 to 0.28 percent from the 2030 baseline.**

16. **Individualized Marketing:** This strategy targets people who are interested in or open to alternative modes of transportation, then provides them with customized contacts and transportation mode information. **Potential to reduce GHG emissions nationally by 0.14 to 0.28 percent from the 2030 baseline.**

17. **Truck-Idling Reduction:** In addition to idling in traffic, drivers may idle their trucks while they are parked to keep the truck warm, allow it to build air pressure for the release of its brakes, or to power auxiliary systems. Reducing idling in turn can reduce fuel use and greenhouse gas emissions. **Potential to reduce GHG emissions nationally by 0.09 to 0.28 percent from the 2030 baseline.**

18. **Bicycle Improvements:** These include bike lanes and off-road paths, which would support non-motorized travel, eliminating VMT. **Potential to reduce GHG emissions nationally by 0.09 to 0.28 percent from the 2030 baseline.**

19. **Information to Support Vehicle Purchases:** This includes campaigns that assign a special designation to vehicles that perform well in order to reduce greenhouse gas emissions and air pollution. **Potential to reduce GHG emissions nationally by 0.09 to 0.23 percent from the 2030 baseline.**

20. **Rail Freight Infrastructure:** Moving goods by rail can be more energy-efficient than moving goods by truck. Therefore, shifting or diverting freight from trucks to rail can reduce greenhouse gas emissions. Infrastructure improvements, financial incentives or disincentives, and other policy

and regulatory actions can encourage shippers to move goods from trucks to rail. **Potential to reduce GHG emissions nationally by 0.01 to 0.22 percent from the 2030 baseline.**

21. **Parking Management:** Changes to parking prices, supply, and other management techniques that can discourage driving are called parking management. Parking management can be used to encourage people to walk, bike, take transit, or use other non-SOV modes to reach their destinations, and to reduce time to search for parking. **Potential to reduce GHG emissions nationally by 0.20 percent from the 2030 baseline.**

22. **Car Sharing:** This describes a system where members pay to rent vehicles as needed on a per-trip hourly basis, either from companies or via peer-to-peer sharing. People who use car-sharing services can access cars without car ownership. Therefore, they may choose to forego owning their own vehicles. **Potential to reduce GHG emissions nationally by 0.05 to 0.20 percent from the 2030 baseline.**

23. **Ride Sharing:** Ride matching, carpooling, and vanpooling jointly are called ride sharing, and can reduce VMT by increasing vehicle occupancies for work trips. Ride sharing may be supported by internet technologies, mobile phones, or programs that reimburse employees for the costs of taxi rides or rental cars in the event of an emergency. **Potential to reduce GHG emissions nationally by 0.0 to 0.2 percent from the 2030 baseline.**

Detailed descriptions and evaluations of these individual strategies are available in Appendix A.

One other potential strategy for reducing greenhouse gas emissions is the use of buses and other non-fixed guideway transit services. Unfortunately, this strategy was not evaluated in Incorporating Greenhouse Gas Emissions or Moving Cooler, and more research is needed to determine its GHG reduction potential. However, the Federal Transit Administration data on average CO2 emissions per passenger mile by mode show that the emission rate from private automobiles is higher than that from bus transit (although the bus transit rate is higher than the various rail rates). Bus transit emission rates are also projected to decrease by 50 percent by 2050 because of technological improvements.[28]

[28] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, 5-35, 5-38.

4.2 GHG REDUCTION POTENTIAL AND COST-EFFECTIVENESS OF PROMISING STRATEGIES

4.2.1 Promising Strategies and the MPO Framework

The MPO's 2012 update to the *Carbon Dioxide, Climate Change, and the Boston Region MPO* report, cited possible MPO actions and partnership opportunities that fall into three categories:

- Creating a more efficient transportation system that has lower GHG emissions
- Promoting fuel efficiency and cleaner vehicles
- Coordinating transportation with land use decisions

Table 4.1 below presents our literature review strategies in context of these categories. The table also documents the strategies' relationship to the GreenDOT goals outlined in Chapter 1. The strategies also fall into general strategy types, which were identified in Section 3.1.

TABLE 4.1
Promising Strategies by Type, Relationship to GreenDOT, and Potential MPO Role in Implementation

Category	Strategy	Strategy Type	Relationship to GreenDOT	Potential MPO Role
Creating a More Efficient Transportation System That Has Lower GHG Emissions	Pedestrian Improvements	Transportation System Planning, Funding, and Design	Promote Healthy Transportation Modes	Fund or Study
	Bicycling Improvements	Transportation System Planning, Funding, and Design	Promote Healthy Transportation Modes	Fund or Study
	Expansion of Urban Fixed-Guideway Transit	Transportation System Planning, Funding, and Design	Promote Healthy Transportation Modes	Fund or Study
	Rail Freight Infrastructure	Transportation System Planning, Funding, and Design	Reduce Transportation-Related GHG	Fund or Study
	Alternative Construction Materials	Construction and Maintenance Practices	Reduce Transportation-Related GHG	Advocate
	Increased Transit Service	Transportation System Management and Operations	Promote Healthy Transportation Modes	Fund or Study

Category	Strategy	Strategy Type	Relationship to GreenDOT	Potential MPO Role
	Transit Fare Reductions	Transportation System Management and Operations	Promote Healthy Transportation Modes	Study
	Carbon Tax or Cap-and-Trade	Taxation and Pricing	Reduce Transportation-Related GHG	Study or Advocate
	Pay-As-You-Drive Insurance	Taxation and Pricing	Reduce Transportation-Related GHG	Study or Advocate
	Vehicle-Miles-Traveled Fees	Taxation and Pricing	Reduce Transportation-related GHG	Study or Advocate
	Congestion Pricing	Taxation and Pricing	Reduce Transportation-Related GHG	Study or Advocate
	Workplace Transportation Demand Management	Travel Demand Management	Reduce Transportation-related GHG	Fund or Study
	Teleworking	Travel Demand Management	Reduce Transportation-Related GHG	Fund or Study
	Compressed Work Weeks	Travel Demand Management	Reduce Transportation-Related GHG	Study
	Individualized Marketing of Transportation Services	Travel Demand Management	Reduce Transportation-Related GHG	Fund
	Ride sharing	Travel Demand Management	Reduce Transportation-Related GHG	Fund or Study
	Car sharing	Travel Demand Management	Reduce Transportation-Related GHG	Fund or Study
Promote Fuel Efficiency and Cleaner Vehicles	Truck-Idling Reduction	Transportation System Management and Operations	Reduce Transportation-Related GHG	Fund or Study
	Reduced Speed Limits	Transportation System Management and Operations	Reduce Transportation-Related GHG	Study or Advocate
	Driver Education and Eco-Driving	Other Public Education	Reduce Transportation-Related GHG	Publicize

Category	Strategy	Strategy Type	Relationship to GreenDOT	Potential MPO Role
	Information on Vehicle Purchases	Other Public Education	Reduce Transportation-Related GHG	Publicize
Coordinate Transportation with Land Use Decisions	Compact Development	Land Use Codes, Regulations, and Policies	Support Smart Growth through transportation investment	Study or Advocate
	Parking Management	Land Use Codes, Regulations, and Policies	Reduce Transportation-Related GHG	Fund or Study

Source: Central Transportation Planning Staff.

4.2.2 Findings on Promising Strategies

The 24 strategies in Table 4.2 below are listed from most to least promising in terms of their maximum ability to affect national transportation emissions. There is an extra strategy in this table (also described in Appendix A) because compressed work week is separated into two distinct programs—required employer-offered compressed work week and compressed work week: mandatory public and voluntary private. Data for these strategies was compiled by the Transportation Research Board in the *Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process* report.[29] The percentages represent the possible reductions in national annual transportation emissions compared to 2005 levels, and the costs are expressed in dollars per metric ton of CO_2e reduced. The Transportation Research Board's 2013 report was used as the primary source of quantitative information since it is the most recent comprehensive compilation of data on this topic. Significantly, it also has converted GHG reduction information from other sources into the same units to facilitate comparison—information is often expressed in different units across different sources.

The table also indicates where there is potential for the Boston Region MPO to directly fund, fund with partnerships, or study/model each strategy. The MPO can directly fund a strategy if it involves expanding a current program, or if the strategy falls under the jurisdiction of a MPO more than that of a Regional Planning Agency (RPA). While this distinction is blurry for regional organizations where the MPO and the RPA are represented by the same regional organization, the difference is more significant for the Boston Region MPO, which is separate from the region's RPA, the Metropolitan Area Planning Council (MAPC). Strategies that may be more appropriate for RPAs and for which the MPO likely

[29] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

would need to work together with MAPC toward implementation are categorized as strategies that the MPO can fund with partnerships. Potential partners for strategies that could be funded with partnerships also include state and local organizations that already conduct outreach for transportation demand management.

Finally, there are other strategies that cannot be funded by the MPO, but could be studied or modeled. While studies alone do not reduce greenhouse gas emissions, they may be useful to support a strategy's implementation.

Also included in this table is information about timing of benefits (short, medium, or long); and the table poses the following questions for each strategy:

- *Technological Feasibility*: Is the technology well developed and proven in practice? What is the likelihood that the technology could be implemented in the near future at the deployment levels assumed in the analysis? Technological barriers can be low-tech as well as high-tech (for example, there may be right-of-way constraints to infrastructure expansion in urban areas).
- *Institutional Feasibility*: Do government agencies have the authority and resources to implement the strategy? What is the administrative ease of running the program; and what are the levels of coordination required among various stakeholders?
- *Political Feasibility*: Is the strategy generally popular or unpopular with any interested stakeholders, elected officials, and the general public? What is the political influence of those supporting versus those opposed to the strategy?

Feasibility is assessed without respect to cost, which was evaluated as part of the cost-effectiveness measure.

TABLE 4.2
Evaluation of Promising Transportation GHG Reduction Strategies [a] (Based on National Data)

Strategy	GHG Reduction [b] (Rating)	GHG Reduction [b] (Pct. Change from 2030 Baseline)	Relative Max. Reduction as Percent of GHG Reduction of Combined Strategies [c]	Direct Cost-Effect. (Rating)	Direct Cost-Effect. [b] (Dollars per unit)	Technological Feasibility [b] (Rating)	Institutional Feasibility [b] (Rating)	Political Feasibility [b] (Rating)	MPO Role
Carbon tax or cap-and-trade	High	2.8–4.6%	15.0%	N/A	N/A	Medium	Medium	Low-to-Medium	Study or Advocate
Driver education/eco-driving	High	0.8–3.7%	12.1%	High[d]	N/A	Low	Low	High	Publicize[f]
Pay-as-you-drive insurance	High	1.1–3.5%	11.4%	High	$30–$90	Low-to-Medium	Low-to-Medium	Medium	Study or Advocate
Compact development	High	0.2–3.5%	11.4%	High	$10	Medium	Low	Low	Study or Advocate
Compressed work week requirement	High	2.4%	11.1%	High	$1	High	Low	Low-to-high	Study
VMT fee	High	0.8–2.3%	7.5%	High	$60–150	Low	High	Low	Study or Advocate
Reduced speed limits	High	1.2–2.0%	6.5%	High	$10	High	Medium-to-High	Low	Study or Advocate
Congestion pricing	High	0.5–1.6%	5.2%	Medium	$340	Low	High	Low	Study or Advocate
Alternative road construction materials	Medium	0.7–0.8%	2.6%	Low-to-High	$0–$770	Medium-to-High	Medium	Medium-to-High	Advocate
Expansion of urban fixed-guideway transit	Medium	0.17–0.65%	2.1%	Low	$1,800–2,000	Medium	High	Medium	Fund or Study
Teleworking	Medium	0.5–0.6%	2.0%	Low	$1,200–2,300	Medium	Low	Medium-to-High	Fund or Study
Increased transit service	Medium	0.2–0.6%	2.0%	Low	$3,000–$3,300	High	High	High	Fund or Study

Strategy	GHG Reduction [b] (Rating)	GHG Reduction [b] (Pct. Change from 2030 Baseline)	Relative Max. Reduction as Percent of GHG Reduction of Combined Strategies [c]	Direct Cost-Effect. (Rating)	Direct Cost-Effect. [b] (Dollars per unit)	Technological Feasibility [b] (Rating)	Institutional Feasibility [b] (Rating)	Political Feasibility [b] (Rating)	MPO Role
Workplace TDM (general)	Medium	0.1–0.6%	2.0%	High	$30–$180	High	Low-to-High	High	Fund or Study
Pedestrian improvements	Low	0.10–0.31%	1.0%	High	$190	High	Low-to-Medium	Medium	Fund or Study
Compressed workweek for government and voluntary private	Low	0.1–0.3%	1.0%	NA	N/A	High	Low	Low-to-High	Study
Transit fare reduction	Low	0.09–0.3%	1.0%	Low	$1,300	High	High	High	Study
Individualized marketing of transportation services	Low	0.14–0.28%	0.9%	High	$90	Medium	Medium	High	Fund [f]
Truck-idling reduction	Low	0.09–0.28%	0.9%	High	$20	High	Medium	Medium	Fund or Study
Bicycle improvements	Low	0.09–0.28%	0.9%	High	$80–210	Medium	Low	Medium	Fund or Study
Information on vehicle purchases	Low	0.09–0.23%	0.8%	Low-to-Medium [e]	N/A	High	High	High	Publicize [f]
Rail freight infrastructure	Low	0.01–0.22%	0.7%	High	$80–200	Medium	Medium	Low-to-High	Fund or Study
Parking management	Low	0.2%	0.7%	N/A	N/A	High	Low	Low	Fund or Study
Car sharing	Low	0.05–0.20%	0.7%	High	<$10	High	Medium	High	Fund or Study [f]
Ride sharing	Low	0.0–0.2%	0.7%	High	$80	High	Low-to-Medium	High	Fund or Study [f]

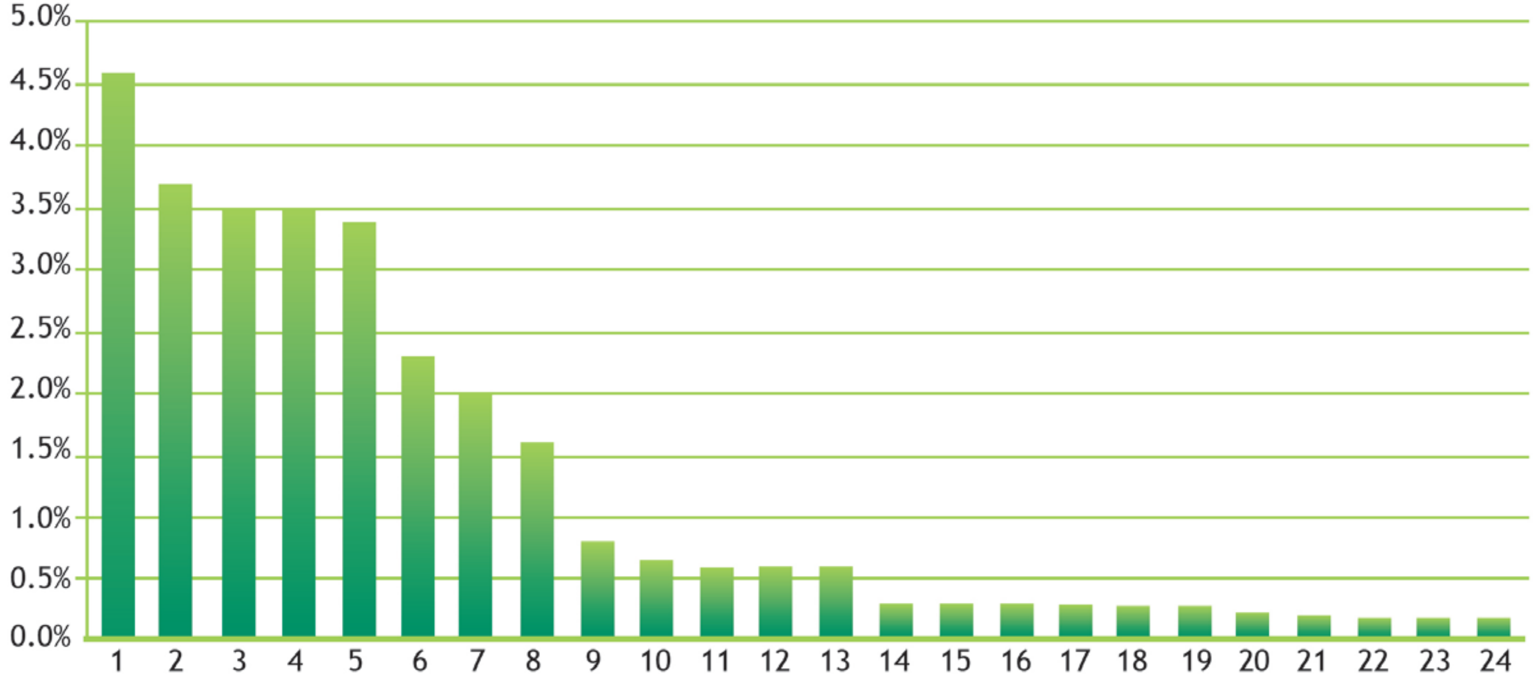
[a] Strategies with the potential to reduce national transportation GHG emissions by at least 0.2 percent.

[b] Source: Transportation Research Board, *Incorporating GHG Emissions* unless otherwise noted
[c] Percent of reduction needed to meet GWSA limits if the GWSA limits are applied nationally and the 2030 goal is set linearly between the 2020 and 2050 limits.
[d] Source: U.S. Department of Transportation, Federal Highway Administration, *Reference Sourcebook for Reducing Greenhouse Gas Emissions from Transportation Sources*, 2012, by Rand Corporation and RSG, Inc., http://www.fhwa.dot.gov/environment/climate_change/mitigation/publications_and_tools/reference_sourcebook/referencesourcebook.pdf p. 204.
[e] Source: Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-96, 5-97.
[f] Publicize potentially using CMAQ funds.

Figure 4.1 below is a bar chart that displays each strategy's relative maximum potential for GHG emissions reductions from the national 2030 baseline. There are large differences between the strategies with the greatest potential and those with relatively small potential. Eight strategies with "high" GHG reduction potential hold roughly four-fifths of the potential for GHG reductions, while the remaining 16 strategies with lower GHG reduction potential represent one-fifth of the total potential. Of the top eight strategies, one can be funded by the MPO—driver education/eco-driving, and the MPO can only publicize information about the program.

Other strategies should not be discounted in importance automatically based on their smaller relative potential for reductions. Many strategies can affect the success of others, or are important for balancing equity and other needs of the transportation system as a whole. For instance, if a VMT fee increases the cost of driving in order to discourage single occupancy vehicles, then there needs to be safe and comfortable transportation choices—such as public transit, walking, and biking—available to former drivers.

FIGURE 4.1
Transportation GHG Reduction Strategies: Maximum Potential for National Emissions Reductions as a Percentage Reduction from National 2030 Baseline



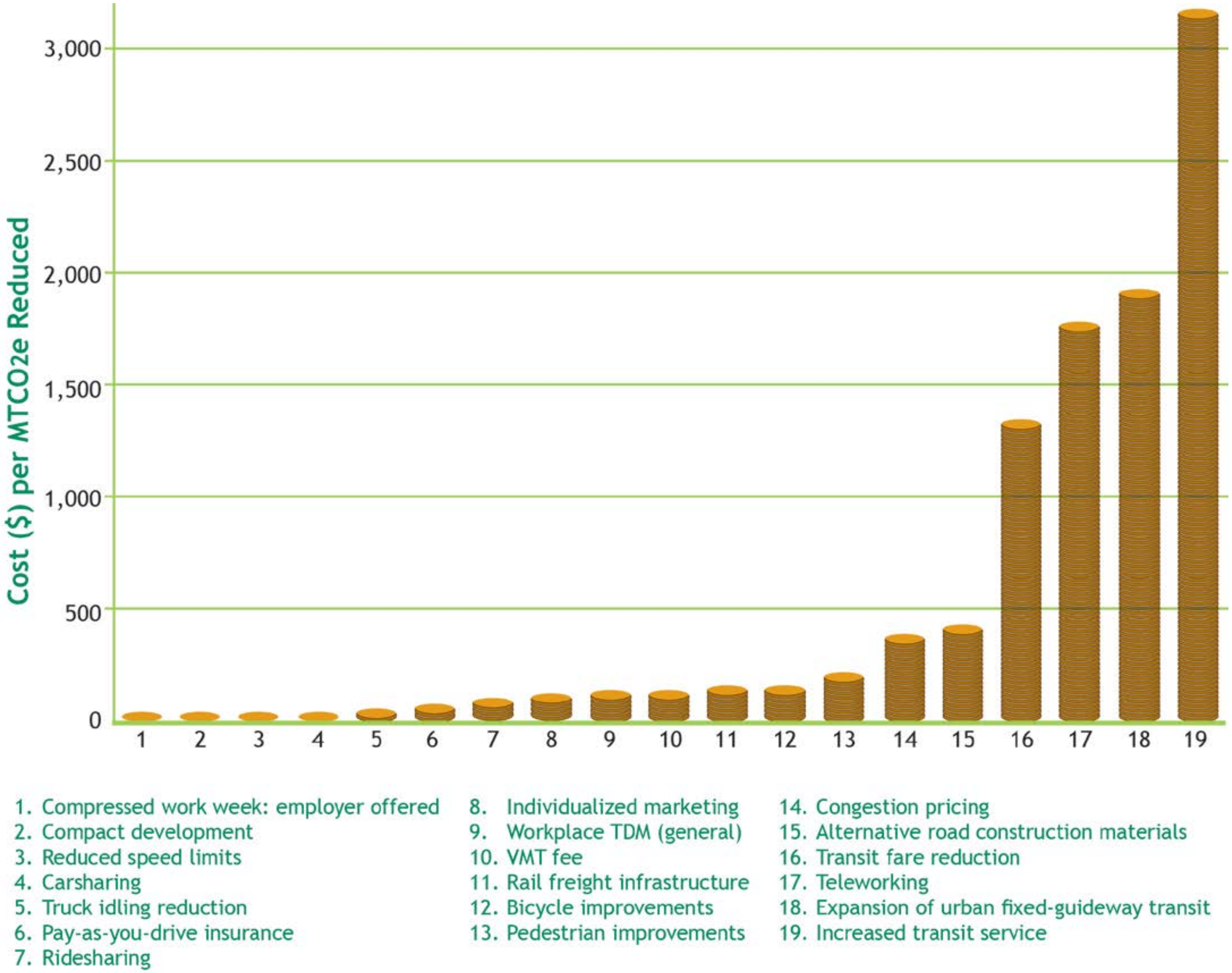
1. Carbon tax or cap-and-trade
2. Driver education/eco-driving
3. Pay-as-you-drive insurance
4. Compact development
5. Compressed work week: employer offered
6. VMT fee
7. Reduced speed limits
8. Congestion pricing
9. Alternative road construction material
10. Expansion of urban fixed-guideway transit
11. Teleworking
12. Increased transit service
13. Workplace TDM (general)
14. Pedestrian improvements
15. Compressed work week: public & private
16. Transit fare reduction
17. Individualized marketing
18. Truck idling reduction
19. Bicycle improvements
20. Information on vehicle purchase
21. Rail freight infrastructure
22. Parking management
23. Carsharing
24. Ridesharing

Source: Incorporating Greenhouse Gas Emissions.

Figure 4.2, below, displays the average direct cost-effectiveness of strategies for which cost information is available. (No cost data is available for carbon tax/cap-and-trade, driver education/eco-driving, compressed government workweek: mandatory public and voluntary private, information on vehicle purchase, or parking management.) Thirteen of the strategies have high cost-effectiveness, from compressed workweek requirements to pedestrian improvements. Four of the strategies typically have low cost-effectiveness: improved transit headways and level of service, expansion of urban fixed-guideway transit, teleworking, and transit fare reduction.

Note that strategies that are not cost-effective may still be valuable to implement. Some of the least-cost effective strategies, namely the transit-focused strategies, and teleworking have the ability to achieve large reductions in total; without these strategies, the largest emission reductions cannot be achieved, In addition, both the transit strategies and teleworking have many other benefits that support cost expenditures, in addition to GHG reduction. These strategies have important mobility and accessibility benefits. A strategy involving capital expenditures on infrastructure may not be cost-effective per ton of GHG reduced, but could be cost-effective compared to infrastructure providing similar transportation services.

FIGURE 4.2
Transportation GHG Reduction Strategies: National Average Direct Cost-Effectiveness [a]



[a] No cost-effectiveness data is available for carbon tax/cap-and-trade, driver education/eco-driving, compressed government workweek with some private, information on vehicle purchase, or parking management; these strategies were not included in the figure.

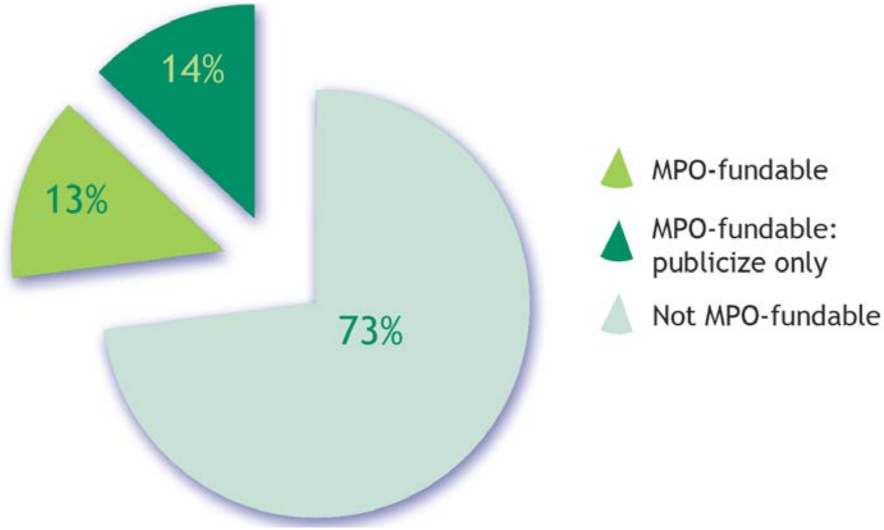
Source: *Incorporating GHG Emissions.*

4.2.3 The MPO's Role in Implementing Promising Strategies

If the maximum potential of all the strategies to reduce GHGs is added and represented by 100 percent total maximum potential, MPO-fundable strategies contribute 27 percent to this total with roughly half of the potential composed of strategies that the MPO can only help publicize (see Figure 4.3). Driver education/eco-driving is responsible for 44 percent of the GHG reduction potential of the group of MPO-fundable strategies, but this can only be publicized by the MPO; 13 other strategies make up the remaining 56 percent, and include:

1. Driver education/eco-driving (publicize only)
2. Expansion of urban fixed-guideway transit
3. Teleworking
4. Increased transit service
5. Workplace TDM (general)
6. Pedestrian improvements
7. Individualized marketing
8. Bicycle improvements
9. Truck-idling reduction
10. Information on vehicle purchase (publicize only)
11. Rail freight infrastructure
12. Car sharing
13. Ride sharing
14. Parking management

FIGURE 4.3
MPO-Fundable GHG Reductions as a Percent of Maximum Potential [a]

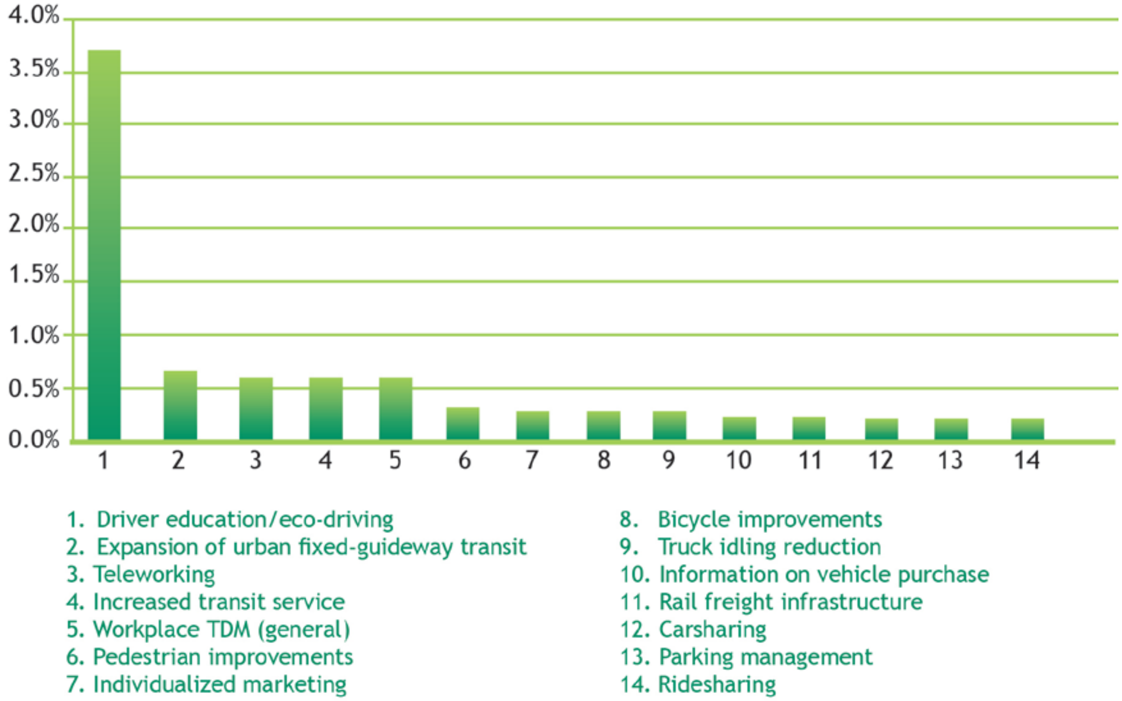


[a] The MPO can only fund publicity for driver education/eco-driver and information on vehicle purchase; it does not have the ability to implement these strategies directly.
Source: Central Transportation Planning Staff.

Note that while the MPO does have the ability to work towards many strategies and affect the region's transportation-related greenhouse gas emissions, the MPO alone likely could not achieve full implementation of some the strategies that it can support with funding. For example, the MPO could provide funding to build protected bicycle lanes, and every protected bicycle lane built helps reduce the region's greenhouse gas emissions. However, the MPO's budget does not individually support aggressive implementation of the bicycle improvement strategy; on its own, the MPO may be unable to fund bike lanes and paths at one-quarter-mile intervals, or even one-mile intervals, in high-density areas throughout the entire region.

Of the strategies that the MPO can fund either directly or with partnerships, the maximum GHG reduction potential of each of the strategies varies greatly. As shown in Figure 4.4, driver education/eco-driving (for which the MPO can publicize only) potentially could reduce greenhouse gas emissions by nearly the same amount potentially achieved by all 13 of the other MPO-fundable strategies combined. Other smaller differences are distinguishable between strategies. For example, expansion of urban fixed-guideway transit has more than 300 percent more potential to reduce GHGs than the ride-sharing strategy. Similarities between different strategies also are of interest: teleworking and general workplace transportation demand management can achieve nearly the same GHG reduction as expansion of urban fixed-guideway transit and increased transit service.

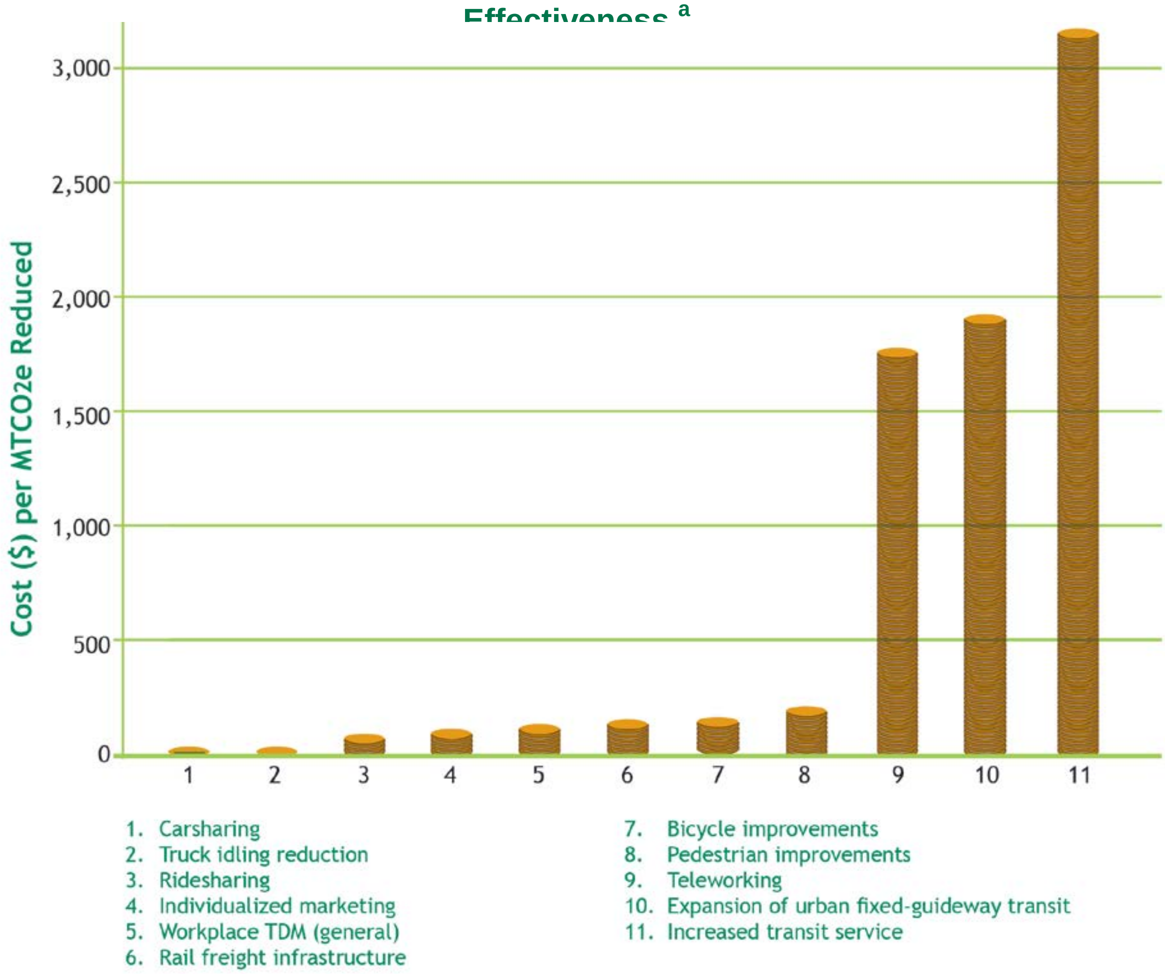
FIGURE 4.4
MPO-Fundable GHG Reduction Strategies: Maximum Potential for Emissions Reductions as Percent Reduction from the National 2030 Baseline



Source: *Incorporating Greenhouse Gas Emissions and Central Transportation Planning Staff.*

Figure 4.5, below, shows that many strategies that the MPO can fund are highly cost-effective. Car sharing, truck-idling reduction, ride sharing, individualized marketing, workplace TDM (general), rail freight infrastructure, bicycle improvements, and pedestrian improvements all have highly cost-effective direct implementation expenses of less than \$250 per $MTCO_2e$. Increased transit service, expansion of urban fixed-guideway transit, and teleworking are much less cost-effective in terms of direct costs. However, these strategies should not be ruled out based on cost alone because they hold potential for large greenhouse gas reductions when they interact synergistically with multiple other cost-effective strategies, and can benefit the transportation system in many ways other than greenhouse gas emissions. Note that cost-effectiveness information is not available for driver education/eco-driving, information on vehicle purchase, and parking management.

FIGURE 4.5
MPO-Fundable GHG Reduction Strategies: National Average Direct Cost-Effectiveness [a]



[a] No cost-effectiveness data is available for the driver education/eco-driving, information on vehicle purchase, and parking management.

Source: *Incorporating Greenhouse Gas Emissions and Central Transportation Planning Staff.*

4.3 COMBINING GHG REDUCTION STRATEGIES

Most individual strategies have modest GHG reductions of less than one percent of total transportation emissions, but combining the effects of multiple strategies could help to achieve larger reductions when paired with other strategies. The GHG reduction potential of individual strategies, however, cannot simply be added together to get the cumulative effect. Before any synergistic effects are taken into account, the effects of each strategy must be multiplied by the effects of the others, resulting in a slightly smaller effect than if the individual reductions were added.

As discussed in Section 3.1, the difference between multiplying the effects and just adding the reductions will be greater when a larger number of strategies are combined.[30] Furthermore, the different strategies interact with each other, some with synergistic effects and others with opposing effects. Strategies that work together synergistically can result in GHG reductions larger than the sum of the reductions of the individual strategies. It is important to keep these factors in mind when considering combinations, or “bundles” of GHG reduction strategies.

In order to see how effective a GHG reduction strategy bundle is at helping meet statewide *Global Warming Solutions Act* limits, we can imagine how far below the national 1990 baseline the bundle can reduce emissions. The Transportation Research Board suggests that combined strategies could achieve five-to-20 percent cuts to transportation emissions in 2030.[31] *Moving Cooler* provides somewhat higher estimates of 12-to-30 percent for 2030 reductions and 18-to-35 percent for 2050 reductions through aggressively implemented strategies (lower estimates) or maximally implemented strategies with economy-wide pricing via a price on carbon, a VMT fee, and pay-as-you-drive insurance (higher estimates).[32] The higher *Moving Cooler* estimates most competitively tackle the GWSA 2020 and 2050 limits.

Moving Cooler examined six strategy bundles, which offer insight into how different strategies might be grouped, and how different strategies influence each other positively or negatively. Strategies are evaluated in terms of multiple variables. In addition to GHG reduction and cost-effectiveness, two sample considerations are equity and net cost savings were considered when bundling strategies. Equity is of particular interest when selecting and balancing strategies; pricing strategies may be made more equitable for low-income groups if the revenues from pricing are used to fund transit and other transportation modes.[33] Another consideration when balancing strategies is overall net cost savings; most strategy bundles realize a net savings when vehicle operation cost savings are weighed against the direct implementation costs.[34]

Each of the six bundles emphasizes a different focus: timing of benefits, magnitude of total GHG reduction, land use and transportation system infrastructure, efficiency, facility pricing, and direct implementation costs. While bundles focused on infrastructure cost more than bundles focused on services, pricing, or regulations, all of the bundles except the facility pricing bundle resulted in vehicle operation cost savings greater than direct implementation costs.

[30] Cambridge Systematics, *Moving Cooler*, p. 35.
[31] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 33.
[32] Cambridge Systematics, *Moving Cooler*, p. 82.
[33] Cambridge Systematics, *Moving Cooler*, p. 35.
[34] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 31.

The bundles demonstrate that strategies can be combined effectively to "provide high-quality transportation services while achieving meaningful GHG reductions." Land use changes and improved transit and transportation options will lead to notable reductions beyond 2030, recommending them to policymakers who are focused on the 2050 GWSA limit.[35]

The next two sections examine two of the strategy bundles analyzed in *Moving Cooler*, the Low-Cost bundle and the Long-Term/Maximum Results bundle.

4.3.1 The Low-Cost Strategy Bundle

The Low-Cost bundle is of particular interest to policymakers who are constrained by cost-effectiveness. Of the 24 strategies that were highlighted in this literature review, the Low-Cost Bundle roughly includes the following GHG reduction strategies, sorted from largest to smallest potential GHG reduction:

- Driver education/eco-driving
- Compact development
- Reduced speed limits
- Congestion pricing
- Workplace TDM (general)
- Pedestrian improvements
- Transit fare reduction
- Truck idling reduction
- Bicycle improvements
- Parking management
- Car sharing
- Ride sharing[36]

In addition to these strategies, the Low-Cost bundle also names intercity tolls, and a number of strategies in two other categories—systems operations and management strategies and multimodal freight strategies. The systems operations and management strategies are:

- Freeway management (ramp metering, variable message signs, active traffic management, and integrated corridor management)
- Incident management, traveler information, and vehicle infrastructure integration

[35] Cambridge Systematics, *Moving Cooler*, pp. 80-83.

[36] Note: While this strategy was not studied in Moving Cooler, it was analyzed by Cambridge Systematics the following year and seems to fall under the Low Cost bundle's "employer-based commute measures."

The multimodal freight strategies listed are:

- Shipping container permits
- Longer combination vehicle permits
- Weigh-in-motion screening
- Weigh station bypass
- Urban consolidation centers[37]

Without economy-wide pricing, at maximum deployment, this bundle achieves 91 percent of the reductions possible with the Long-Term/Maximum Results bundle, the bundle with the greatest GHG reduction potential. If economy-wide pricing measures are put in place, the GHG reductions achieved by both bundles improve dramatically, and the Low-Cost bundle performs within one-tenth the cumulative 2010 to 2050 effect of the Long-Term/Maximum Results bundle.[38]

However, Cambridge Systematics notes that other strategies such as transit expansion may be needed to balance the Low-Cost bundle. Because this bundle was exclusively selected by cost, other important transportation concerns were neglected in some cases. For example, if compact development is not implemented together with transit expansion, there may negative effects such as congestion, reduced mobility, and equity concerns.[39] Because of these limitations of the Low-Cost bundle, it is recommended that if this bundle were used to guide selection of GHG reduction strategies, then transit expansion and increased transit services should be studied at a minimum, because, while they are capital-intensive, transit serves an important function in the overall transportation system.

4.3.2 The Long-Term/Maximum Results Strategy Bundle

The Long-Term/Maximum Results bundle achieves the maximum emissions reduction by 2050, making it interesting to policymakers who seek to achieve the long-term 2050 limit established in the Global Warming Solutions Act. It also offers a more robust transportation system overall, with the potential to address congestion, reduced mobility, and equity concerns posed by the Low-Cost bundle. Of the 24 strategies that were highlighted in this literature review, the Long-Term bundle roughly includes the following GHG reduction strategies, sorted from largest to smallest potential GHG reduction[40]:

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[37] Cambridge Systematics, *Moving Cooler*, p. 62.
[38] Cambridge Systematics, *Moving Cooler*, pp. 72-73.
[39] Cambridge Systematics, *Moving Cooler*, pp. 62-63.
[40] Cambridge Systematics, *Moving Cooler*, p. 49.

- Driver education/eco-driving
- Compact development
- Reduced speed limits
- Congestion pricing
- Expansion of urban fixed-guideway transit
- Increased transit service
- Workplace TDM (general)
- Pedestrian improvements
- Transit fare reduction
- Bicycle improvements
- Rail freight infrastructure
- Parking management
- Car sharing

In addition to these strategies, the Long-term/Maximum Results bundle also names intercity tolls, intercity passenger rail expansion, high-speed passenger rail expansion, high-occupancy lanes, urban non-motorized zones and a number of strategies in two other categories—systems operations and management strategies and multimodal freight strategies. The systems operations and management strategies are:

- Freeway management (ramp metering, variable message signs, active traffic management, and integrated corridor management)
- Incident management, road weather management, signal management, traveler information, and vehicle infrastructure integration
- Bottleneck relief
- Highway capacity expansion

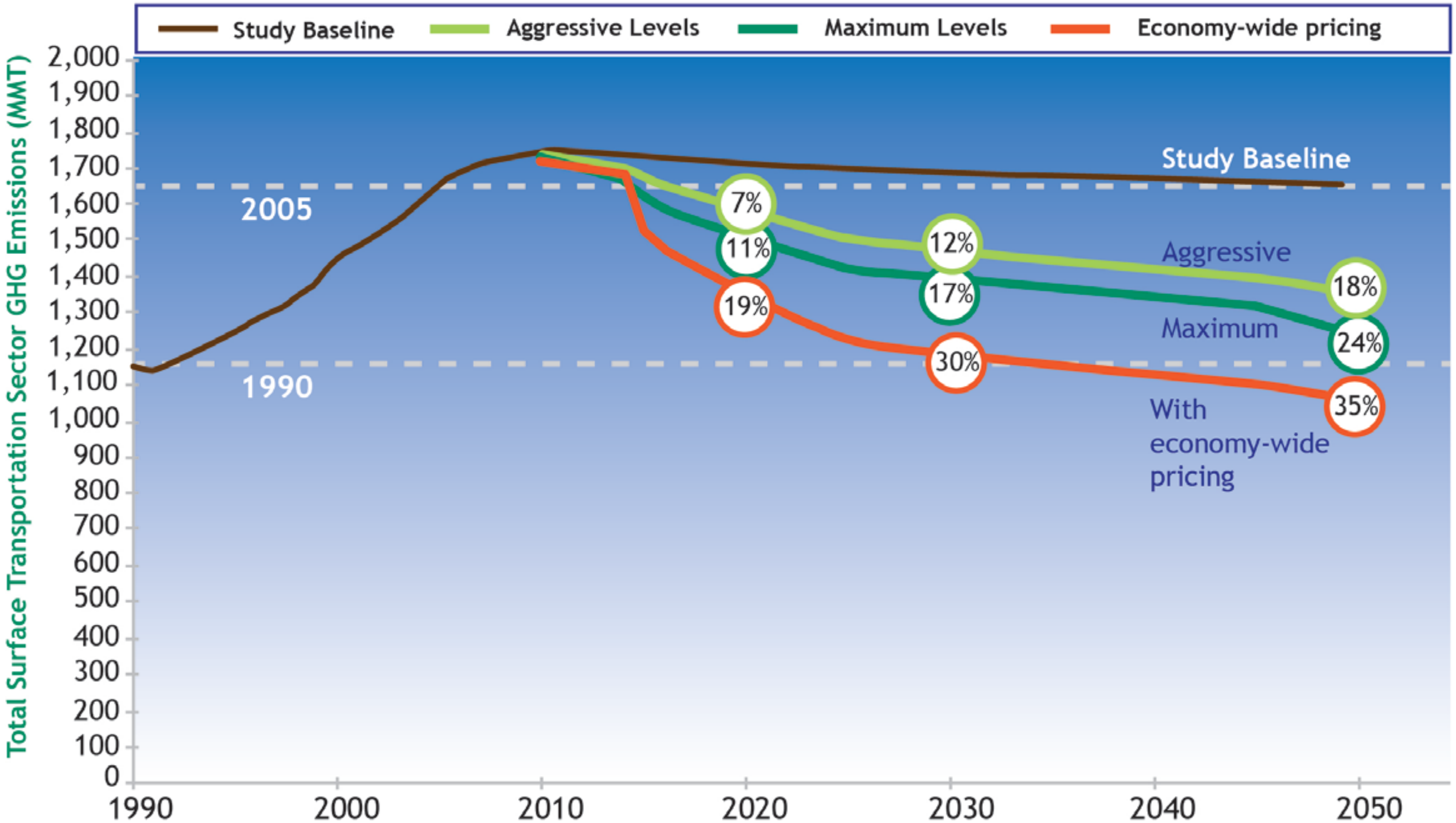
In addition to rail freight infrastructure, the other multimodal freight strategies are:

- Marine system improvements
- Shipping container permits
- Longer combination vehicle permits
- Weigh-in-motion screening
- Weigh-station bypass
- Truck-stop electrification
- Truck-only toll lanes
- Urban consolidation centers[41]

[41] Cambridge Systematics, *Moving Cooler*, p. 49.

Figure 4.6 demonstrates the reduction potential of these combined strategies at aggressive deployment, maximum deployment, and aggressive deployment with economy-wide pricing. Without economy-wide pricing, the figure shows that maximum deployment reduces GHG by four-to-six percent more than aggressive development, depending on the target year. Aggressive deployment with economy-wide pricing reduces GHG by eight-to-11 percent more than maximum deployment without economy-wide pricing.

FIGURE 4.6
National Transportation GHG Baseline: 1990, 2005, and Future Levels



1990 and 2005 GHG Emissions - Combination of DOA AEO data and EPA GHG Inventory data
Study Baseline - Annual 1.4 percent VMT growth combined with 1.9 percent growth in fuel economy
Aggressive - GHG emissions from bundle deployed at aggressive level without economy-wide pricing measures
Maximum - GHG emissions from bundle deployed at maximum level without economy-wide pricing measures
Economy-Wide Pricing - Includes aggressive deployment of pay-as-you-drive (PAYD) insurance and both the VMT and fuel economy impact of the aggressive deployment of an indexed carbon price through 2050

Source: Cambridge Systematics, *Moving Cooler.*

The strategies in the Long-Term/Maximum Results combine to a 30-percent reduction from the national baseline in 2030. When exploring what these national data signify in Massachusetts with regard to the GWSA, there are two major differences. At the national level, emissions increased roughly 40 percent from 1990 to 2005, but in Massachusetts, emissions increased only 13 percent between the two baselines. While implementing all the strategies at the national level essentially brings 2030 emissions levels even with the 1990 levels, in Massachusetts the same reduction from all the strategies may bring emissions levels below 1990 levels if the 2030 Massachusetts baseline stays at 2005 levels, as it is projected to do at the national level. While no business-as-usual baseline has been projected yet for the Massachusetts transportation sector through 2030, data through 2012 show Massachusetts emissions have stayed at 2005 levels so far.

Again, the potential for each individual reduction strategy will also be different in Massachusetts than it will be at the national level. For example, some of the strategies apply only to urban areas or can achieve greater reductions in more urban areas compared to rural areas. Since Massachusetts is more urban and more densely developed than the nation on average, these types of strategies may yield greater reductions in the state and in the Boston region if they are implemented. Congestion pricing and transit fare reduction are two such strategies. Further study is needed to quantify the effects of each strategy.

4.4 QUESTIONABLE LONG RANGE SOLUTIONS

As noted in Table 3.1, several potential GHG reduction strategies have low or negative effects on greenhouse gas emissions when induced demand is taken into account and impacts are examined over the long term. Induced demand occurs when roadway capacity increases, and attracts more drivers; thus, total VMT may be higher than what would it would be otherwise. While these strategies have other benefits, their role in GHG reduction is limited.

4.4.1 Capacity Expansion and Bottleneck Relief

Two potential GHG reduction strategies—more aggressive capacity expansion and nationwide top 100 to 200 bottleneck relief—are noteworthy in that while they may decrease GHG emissions in the medium term (by 2030), they increase emissions in the long term (by 2050). In Massachusetts, in the context of the Global Warming Solutions Act’s 2050 GHG emission reductions limit, these strategies are not effective emission solutions. Furthermore, capacity expansion and bottleneck relief are not cost-effective; not only are they costly to implement, but also their cost per metric ton of GHG reduced is high because of the lack of reductions achieved.

According to the methodology in *Moving Cooler,* which calculates impacts through 2050 and takes induced demand for future VMT into account, capacity expansion has a net effect of increasing greenhouse gas emissions. If increased user fees are put in place to pay for the capacity expansion, this strategy would have a net effect of increasing GHGs by four-to-15 $MMTCO_2e$. However, if no increased user fees were applied, this strategy would produce higher greenhouse gas emissions, from 440-to-560 $MMTCO_2e$, which is less than one percent of the *Moving Cooler* baseline. The Urban Land Institute notes that this result "underscores the importance of pricing strategies."[42] The Transportation Research Board adds that the cost-effectiveness of capacity expansion is undefined since net GHG benefits through 2050 were negative; GHG emissions increased rather than decreased.[43]

If only GHG impacts anticipated through 2030 are examined, as in Transportation Research Board's findings based on *Moving Cooler*'s calculations, capacity expansion of a 25-to-100 percent increase in economically justified investments above current levels results in a 0.07-to-0.29 percent emissions reduction in 2030. (Economically justified capacity expansion was based on analysis using the FHWA Highway Economic Requirements System (HERS) model.)[44]

Similarly, improving the top-100-to-200 bottlenecks nationwide by 2030 would result in a 0.05-to-0.21 percent emissions reduction in 2030. The moderate decreases in the medium term could mistakenly be interpreted as progress towards the long-term 2050 GHG reduction limit in a snapshot of the 2030 mid-point, despite increasing net emissions between 2010 and 2050. [45] These strategies emphasize that a long-term analysis that takes full account of long-term induced demand is needed to accompany short- and mid-term analysis.

4.4.2 Transportation System Management with Induced Demand

Transportation system management strategies are an important category of strategies that can be used to reduce greenhouse gas emissions. Transit system strategies such as improved headways and level-of-service (LOS), and truck system strategies such as idling reduction are examples of transportation system management strategies that can achieve moderate GHG reductions. Many roadway system-focused strategies, however, have little or no ability to reduce emissions once induced demand is included the analysis.

[42] Cambridge Systematics Inc., *Moving Cooler*, p. 41.
[43] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.
[44] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.
[45] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.

Traffic management is one example of a strategy that reflects lower GHG emissions savings after induced demand is taken into account. The Transportation Research Board's analysis assumes deployment of traffic management strategies on freeways and arterials at the rate of 700-to-1,400 miles per year nationwide in locations of the greatest congestion. The TRB found that while large reductions of 0.89-to-1.3 percent were possible through reduced congestion, induced demand occurring on less congested roads consumed most of the savings, for net reductions of only 0.07-to-0.08 percent.[46]

Other transportation system management strategies that do not significantly reduce greenhouse gas emissions are presented in Table 4.3, below.[47]

TABLE 4.3
Transportation System Management Strategies with Limited Potential

Strategy Name	Description	GHG Reduction (2030) before Induced Demand	Actual GHG Reduction (2030)
Signal control management	Upgrade to closed loop or traffic adaptive system	0.01–0.10%	0.00%
Real time traffic information	511, USDOT website, personalized information	0.02–0.07%	0.00%
Ramp metering	Centrally controlled	0.12–0.22%	0.01%
Active traffic management	Speed harmonization, lane control, queue warning, hard shoulder running	0.24–0.29%	0.01-0.02%
Integrated corridor management	Multiple strategies	0.24–0.29%	0.01-0.02%
Incident management	Detection and response, including coordination through traffic management center	0.24–0.34%	0.02-0.03%

Source: Transportation Research Board, Incorporating Greenhouse Gas Emissions.

[46] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.
[47] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.

4.5 GHG REDUCTION STRATEGY CONCLUSIONS

4.5.1 Economy-Wide Pricing

Ultimately, economy-wide pricing is critical to achieving the greatest greenhouse gas emission reductions. It may be difficult to bring Massachusetts transportation emissions below 1990 levels and help the state reach the Global Warming Solutions Act limits, particularly the more ambitious 2050 limits, without adopting economy-wide pricing strategies such as a carbon tax and/or cap-and-trade.

See the call out box to the right for details of how a price on carbon could be implemented in Massachusetts.[48,49]

To illustrate the effect of economy-wide pricing, Table 4.4 below shows the effect of including economy-wide pricing measures in the Low-Cost strategy bundle in terms of percentage increase in cumulative GHG reduction effect from 2010 through 2050. Note that that effect of the baseline Low-Cost bundle at maximum deployment is 26 percent higher than the effect at aggressive deployment; the level of deployment plays a crucial role as well.[50]

Carbon Pricing in Massachusetts

A draft of bill S.1747, An Act Combating Climate Change, was introduced in fall 2015 and shows how Massachusetts could adopt a price on carbon. The Act aims to levy fees on fuels that emit CO_2, which would drive demand and emissions down. The Act would distribute the proceeds of the fee equally to everyone through a rebate, which would avoid raising taxes. Residents who use more energy than average would pay more in fees than they get back in rebates. Most residents (the bottom 60 percent) would actually get rebates. Fees would be set at $10 per ton of CO_2 in the first year and increase $5 per ton each year until they reach $40 per ton.

[48] Senator Mike Barret, An Act Combating Climate Change: the basics, 2015, http://senatormikebarrett.com/wp-content/uploads/2015/10/Carbon-Pricing-the-basics.pdf.
[49] The 189th General Court of Massachusetts, Bill S.1747, 2015, https://malegislature.gov/Bills/189/Senate/S1747.
[50] Cambridge Systematics, *Moving Cooler*, pp. 72-73.

TABLE 4.4
Impacts of Economy-Wide Pricing Measures upon the Low Cost Strategy Bundle at Aggressive and Maximum Deployment

Strategy Bundle	Aggressive Deployment: Percent increase in Cumulative Effect (2010–2050)	Maximum Deployment: Percent increase in Cumulative Effect (2010–2050)
Low-Cost Bundle	--	--
Bundle + PAYD	18%	22%
Bundle + PAYD + VMT Fees	28%	57%
Bundle + VMT Effect of Carbon Price	10%	50%
Bundle + VMT effect of Carbon Price + MPG effect of Carbon Price	53%	157%

MPG = Miles per gallon. PAYD = Pay-As-You-Drive Insurance. VMT = Vehicle-miles traveled.
Source: Cambridge Systematics, *Moving Cooler*

Ultimately, the MPO cannot implement economy-wide pricing strategies; it can only advocate for these strategies.

4.5.2 Public Transportation Improvements

Of the MPO-fundable strategies, improvements to public transportation through expansion of urban fixed-guideway transit and increased transit service have the potential to achieve relatively large GHG reductions. Many reports suggest that investment in transit could play a significant role in efforts to reduce GHG emissions by shifting travelers to more efficient modes of transportation. *Moving Cooler* makes this point: “Transit investments may be particularly critical if significant pricing strategies are in place, to provide travelers a viable, lower cost alternative to driving.”[51] Transit also importantly ties in to land-use strategies and compact development. Transit-oriented development projects nationwide have been found to generate 44 percent fewer weekday vehicle trips, on average, than the amounts estimated by the Institute for Transportation Engineers.[52]

Although transit infrastructure and service improvements have low cost-effectiveness per ton of GHG reduced for the implementing agency, these strategies can yield net savings overall because of large reduced personal vehicle operating costs for users.

[51] Cambridge Systematics Inc., *Moving Cooler*, p. 42.
[52] Transportation Research Board, Transit Cooperative Research Program, *Effects of TOD on Housing, Parking, and Travel*, 2008, Washington, D.C., http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_128.pdf (accessed March 20, 2015).

Ridership is an important factor in determining the cost-effectiveness and benefits of specific projects, which could be negative if ridership is low.[53]

Public transportation can provide equity benefits in the Boston region by alleviating part of any mobility loss because of pricing measures. Strategies that improve public transportation can provide a higher proportion of benefits to lower-income groups since these groups rely more on public transportation than other groups. Similarly, this strategy will provide a higher proportion of benefits to other groups with fewer transportation mode choices, such as those who reside in rural areas and individuals without access to automobiles.[54] However, rising property values and rent increases associated with transit improvements can potentially result in displacement of lower-income residents; housing measures may be needed to ensure the most equitable outcomes.[55]

Transit has been linked to improved job access, access to educational opportunities (in this way supporting increased employment), and access to preventative health care. Following the start of new transit services, increased job participation has been found for low-wage workers, demonstrating the critical role transit can play in employment opportunities. Improved access to preventative health care can help individuals avoid the need for costlier emergency care visits, resulting in cost savings.[56]

4.5.3 Healthy Transportation Improvements

Improvements to pedestrian and bicycle accommodations are two other MPO-fundable strategies that are beneficial in multiple ways. In addition to supporting GHG reduction, they have public health and safety benefits and are cost-effective. Both modes also can generate equity benefits. *Moving Cooler* states that investment in pedestrian and bicycle modes "can have substantial positive equity effects by increasing mobility for lower income groups and those without significant access to vehicles." Persons without significant access to vehicles include youth, the elderly, disabled persons, lower income individuals, or individuals without driver permits.

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[53] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 33-34.
[54] Cambridge Systematics Inc., *Moving Cooler*, p. 74.
[55] Dukakis Center for Urban and Regional Policy, Northeastern University, Maintaining Diversity in America's Transit-Rich Neighborhoods: Tools for Equitable Neighborhood Change, http://www.northeastern.edu/dukakiscenter/transportation/transit-oriented-development/maintaining-diversity-in-americas-transit-rich-neighborhoods/ (accessed March 25, 2014).
[56] National Cooperative Highway Research Program, Selected Indirect Benefits of State Investment in Public Transportation, Research Results Digest 393, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_393.pdf.

Having walking and bicycling as newly available transportation options would enhance the ability of individuals in these groups to access needed services.[57]

Bicycle and pedestrian strategies also are cost-effective in terms of reducing GHG emissions. These modes offer substantial vehicle cost savings; when the costs of implementation are considered together with vehicle cost savings for users, there are net savings of \$600 to \$700 per $MTCO_2$.[58]

These strategies also generate benefits in terms of increased physical activity and improved public health. Around 70 percent of American adults do not achieve recommended levels of physical activity, and sedentary lifestyles are associated with the rapid increase in the percentage of Americans that are overweight and obese. Environments that are unsafe for walking and biking influence decisions not to choose these transportation options. However, if these modes can be made safer and allow more people to walk and bike, a great health benefit could be realized.[59,60]

Pedestrian and bicycle improvements, like transit, benefit from the presence of compact development. These non-motorized modes support transit use by making connections to and from transit stops, and, like transit, are "much more effective" where destinations are close together in densely developed areas.[61]

4.5.4 Workplace-Focused Strategies

Many of the MPO-fundable GHG reduction strategies target greenhouse gas emissions associated with the workplace. Teleworking has the third-greatest potential of the MPO-fundable strategies and workplace TDM has the fifth-greatest potential. The ride matching, carpooling, and vanpooling strategy can also help to reduce workplace emissions.

Quality of life and mobility also may be gained from workplace-focused GHG reduction strategies. Benefits of teleworking identified by the Environmental Protection Agency (EPA) and Congress include "enhanced worker productivity and morale, improved employee attraction and retention, and reduced overhead

[57] Cambridge Systematics Inc., *Moving Cooler*, p. 74.
[58] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49, 5-53.
[59] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-49, 5-53.
[60] Centers for Disease Control and Prevention, "Obesity and Overweight," http://www.cdc.gov/nchs/fastats/obesity-overweight.htm (accessed March 6, 2015).
[61] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-6.

expenses." Telework also can enhance mobility and productivity of travel (working during transit travel). [62]

Workplace-focused strategies can offer net savings. General workplace TDM has been found to result in large vehicle cost savings for employees.[63] Carpool programs realize a net savings when private vehicle operating costs are included in cost-effectiveness. Vanpool programs likewise can cover most, if not all, of their purchase, operating, and administrative costs through subscription fees, as individuals save on vehicle operating costs. [64]

[62] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-77, 5-81.
[63] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-74, 5-77.
[64] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-87, 5-91.

Chapter 5—Inventory and Evaluation of MPO Investments

5.1 MPO INVESTMENT PROGRAMS

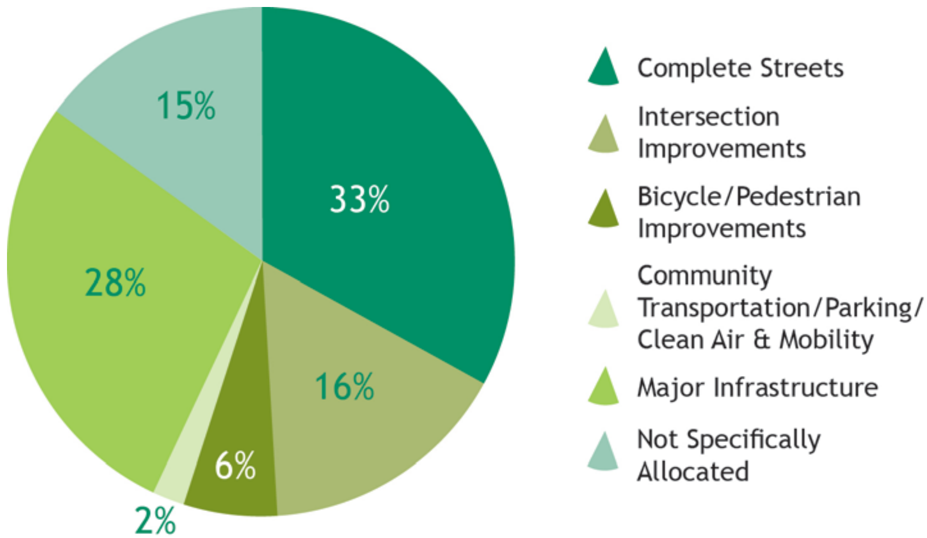
The MPO recently adopted its LRTP, *Charting Progress to 2040,* which includes funding for maintenance and expansion of the region's transportation system under different investment programs. As part of the LRTP development, the MPO conducted a scenario planning process to help finalize its goals and objectives and determine how best to program their funding to meet those goals and objectives through different investment programs. The goal categories are:

- Safety
- System Preservation
- Capacity Management/Mobility
- Clean Air and Clean Communities
- Transportation Equity
- Economic Vitality

The MPO uses its goals and associated objectives to evaluate and rank projects and programs to be funded over the next 25 years in its LRTP and more specifically over the next five years in the TIP. As shown above, the MPO's Clean Air and Clean Communities is one of six goal areas. This goal addresses the reduction of GHG emissions. The MPO considers all goal areas when deciding which projects will be programmed in the LRTP and TIP. The goal areas also are used when considering studies that will be performed as part of the MPO's annual UPWP.

The MPO chose to program its LRTP using a set of investment programs as shown in Figure 5.1.

FIGURE 5.1
MPO LRTP Funding for Investment Programs



Source: Central Transportation Planning Staff.

As discussed in Section 2.1.1, several of these investment programs—including Intersection Improvements, Complete Streets, Bicycle Network and Pedestrian Connections, Community Transportation and Parking, and transit projects included in the Major Infrastructure category—relate directly to the MPO's Clean Air/Clean Communities goal with its objective of reducing GHG emissions.

Many of the projects that have been funded in past TIPs fall into the Intersections Improvements, Complete Streets, and Bicycle and Pedestrian improvements programs. Shuttle services have been funded in the past under older Suburban Mobility and Clean Air and Mobility programs. Any new shuttle service projects would now fall into the new Community Transportation investment program. The MPO flexed highway funding to major infrastructure transit projects, including the completed Assembly Square MBTA station and to the proposed Green Line Phase II project extending the Green Line from College Avenue in Somerville to Mystic Valley Parkway in Medford.

As part of this study, MPO staff inventoried projects that have been funded, studied, or analyzed by the MPO, according to investment category. Projects in each investment category then were compared to determine the projected range of GHG reductions within that investment category. GHG emissions were calculated as reductions in CO_2 for this analysis. The reductions can be calculated in different ways, whether using the travel demand model or through off-model calculations.

Calculation methodologies are described in the next section, followed by the GHG impacts and cost-effectiveness of the different MPO investment programs.

5.2 EXISTING AND PROPOSED GHG EMISSIONS CALCULATION TOOLS

5.2.1 Existing GHG Emissions Calculation Tools

The MPO's regional travel demand model has the ability to forecast GHG emissions associated with highway and transit major infrastructure projects. In order for the travel-demand model to be effective, the project must meet certain capacity-adding characteristics, change the network connectivity, alter tolling structure, or change use policies such as a high-occupancy-vehicle lane. For highway projects, this could include added connectivity or increased capacity changes to the transportation network. For transit projects, it can include new transit stations, lines, or parking facilities. Other characteristics could be changes to fares, travel times, or frequency.

In addition to capacity-adding projects, it is also important to monitor and evaluate the GHG impacts of other projects that do not have these characteristics, including maintenance and operations projects. In order to monitor and evaluate the impacts of these projects, MassDOT and the MPOs developed spreadsheet analysis approaches for identifying the anticipated emission impacts of different project types. The data and analysis required by MPO staff to conduct these calculations using the spreadsheet analysis is typically derived from functional design reports submitted for projects at the 25 percent design phase.

All calculations, whether analyzed using the travel-demand model or the spreadsheet analysis approach, used the same emission factors to provide equitable comparisons. Emission factors used for calculating emissions changes were determined using the EPA's latest emissions model, Motor Vehicle Emissions Simulator (MOVES) 2014 for passenger vehicles and trucks. Transit vehicle emissions were obtained from FTA and EPA guidance documents. MOVES 2014 requires a wide range of input parameters, including inspection and maintenance program information and other data, such as fuel formulation and supply, speed distribution, vehicle fleet mix, and fleet age distribution. Inputs used for this analysis were received from the Massachusetts Department of Environmental Protection; and include information about programs that were submitted to the EPA as the strategy for the Commonwealth to attain ambient air-quality standards.

Intersection Improvements

An intersection reconstruction or signalization project typically reduces delays and idling, therefore reducing GHG emissions.

- Step 1: Calculate the AM-peak-hour total intersection delay (in seconds)
- Step 2: Calculate the PM-peak-hour total intersection delay (in seconds)
- Step 3: Select the peak hour with the longer intersection delay
- Step 4: Calculate the selected peak-hour total intersection delay with improvements
- Step 5: Calculate the vehicle delay in hours per day (assumes peak-hour delay is 10 percent of daily delay)
- Step 6: Input the MOVES emission factors for arterial idling speed
- Step 7: Calculate the net emissions change in kilograms per day
- Step 8: Calculate the net emissions change in kilograms per year (seasonally adjusted)
- Step 9: Calculate the cost-effectiveness (first year cost per kilogram of emissions reduced)

Complete Streets

Complete Streets projects can increase transportation options by adding new sidewalks and bicycle facilities. They also may include roadway and intersection reconstruction or signalization projects within a corridor that typically reduce delays and idling, therefore reducing GHG emissions. Roadway improvements may also help to improve transit operations in the corridor. The following steps calculate the sidewalk and bicycle benefits of the project. The steps outlined above under Intersection Improvements are performed if the project includes them.

- Step 1: Calculate the estimated number of one-way bicycle and walk miles of travel based on the population residing in the communities of the facilities service area and the communities' bicycle and pedestrian commuter mode share
- Step 2: Calculate the reduction in vehicle miles traveled per day and per year (assumes the facility operates 365 days per year)
- Step 3: Input the MOVES emission factors for the average commuter travel speed (assumes 35 mph)
- Step 4: Calculate the net emissions change in kilograms per year (seasonally adjusted)
- Step 5: Calculate the cost-effectiveness (first year cost per kilogram of emissions reduced)

Calculations also were performed on the following project types in previous TIPs; however there are no projects of these types in the current FFY 2016–2020 TIP.

Pedestrian and Bicycle Infrastructure

A shared-use path that would enable increased walking and biking and reduced automobile trips.

- Step 1: Calculate the estimated number of one-way trips based on the percentage of workers residing in the communities of the facilities' service area and the communities' bicycle and pedestrian commuter mode share
- Step 2: Calculate the reduction in vehicle miles traveled per day and per year (assumes each trip is the length of the facility; assumes the facility operates 200 days per year)
- Step 3: Input the MOBILE 6/MOVES emission factors for the average commuter travel speed (assumes 35 mph)
- Step 4: Calculate the net emissions change in kilograms per year (seasonally adjusted)
- Step 5: Calculate the cost-effectiveness (first year cost per kilogram of emissions reduced)

New and Additional Transit Service

A new bus or shuttle service that reduces automobile trips.

- Step 1: Determine vehicle emission rates for automobiles operating at 35 mph and the new bus operated at 30 mph
- Step 2: Calculate vehicle miles traveled and emission savings from the private automobile
- Step 3: Calculate the bus route miles and emissions for the new bus route
- Step 4: Add the impact of the new bus emissions to the emissions from private automobiles
- Step 5: Calculate the net emissions change in kilograms per year (seasonally adjusted)
- Step 6: Calculate the cost-effectiveness (first year cost per kilogram of emissions reduced)

Park-and-Ride Lot

A facility that reduces automobile trips by encouraging HOV travel through carpooling or transit.

- Step 1: Establish number of parking spaces with average utilization rate (the default average utilization rate is 85%)
- Step 2: Determine the mode split of future users prior to lot construction (drive alone, carpool/vanpool, walk/bicycle/transit/other) and the future mode split of those leaving the lot (carpool/vanpool, transit, walk/bicycle/transit/other)
- Step 3: Determine distance to primary employment center and average peak hour travel speed (35 mph is the default travel speed)
- Step 4: Calculate existing conditions and future conditions
- Step 5: Calculate the net emissions change in kilograms per year (seasonally adjusted)

- Step 6: Calculate the cost-effectiveness (first year cost per kilogram of emissions reduced)

Bus Replacement

A new bus that replaces an old bus with newer, cleaner technology.

- Step 1: Determine emission rates for the existing bus and the new bus purchase
- Step 2: Calculate the fleet vehicle miles per day
- Step 3: Calculate the net emissions change in kilograms per year (default operating days per year is 301)
- Step 4: Calculate the cost-effectiveness (default bus life is 12 years)

5.2.2 Proposed GHG Emission Calculation Tools

MassDOT SHRP2 GHG Tool and Process Evaluation Project

The MPO currently uses the tools described above (the travel demand model for regionally significant projects and the spreadsheet analysis for the smaller projects) to calculate a project’s impact on GHG emissions in the region. MassDOT recently received Strategic Highway Research Program (SHRP2) funding from the Federal Highway Administration (FHWA) to address how MassDOT and the MPOs estimate project-related GHG emissions and how those outputs inform planning and the project selection process. This funding will support MassDOT, in collaboration with the MPOs, to identify new tools and develop practices to help the Commonwealth to comply with federal and state laws.

MassDOT identified the challenges to be addressed by this project, including:

- MassDOT’s statewide GHG projection modeling tool is resource intensive and runs only every four years, making it challenging to produce timely projections of transportation sector emissions.
- MPOs are required to assess and consider the GHG impacts of the LRTPs and TIPs, including the projects within these plans, but MPOs have variable capacities for using the tools available to fulfill this requirement.
- It can be difficult to estimate GHG impacts early enough in the project development process to have meaningful data to affect project selection.
- MassDOT does not have an established system for assessing the GHG impacts of its highway maintenance activities nor a method by which GHG impacts of maintenance are considered in decision-making processes.
- This project presents an opportunity to improve the consideration of GHG emissions in freight planning.

The MassDOT study will review and evaluate how MassDOT and MPOs estimate project-level and statewide GHG emissions with two goals:

- Ensure the early-stage project development and selection processes, including those for highway maintenance activities, utilize the most appropriate methods for estimating and considering GHG impacts of projects, in order to assist MPOs and MassDOT in meeting all requirements under the Global Warming Solutions Act
- Improve methods of forecasting transportation sector GHG emissions in Massachusetts, and support the further development of data-driven plans, strategies, and targets

The MassDOT study also will review how MassDOT coordinates with MPOs to measure and track progress toward reaching GHG goals using performance measures. This effort will assist MassDOT in complying with reporting requirements under the Global Warming Solutions Act, and will prepare MassDOT for the performance management requirements under MAP-21 and Fixing America's Surface Transportation (FAST) Act.

Energy and Emissions Reduction Policy Analysis (EERPAT) Tool

The FHWA developed the Energy and Emissions Reduction Policy Analysis (EERPAT) tool to compare, contrast, and analyze various GHG reduction policy scenarios for the state's transportation sector. This tool estimates GHG emissions from surface transportation, including fuel usage (and electricity usage for battery charging) by autos, light trucks, transit vehicles, and heavy trucks.

The EERPAT tool is a policy analysis tool that complements tools such as the EPA's MOVES (described earlier) by providing a rapid analysis of many scenarios that combine effects of various policy and transportation system changes. It was developed to address a wide range of factors, from changes in population demographics, land use characteristics, transportation supply, vehicle fleet characteristics, demand management programs, effects of pricing and congestion, through to the carbon intensity of fuels and electric power generation.

MassDOT is currently working with FHWA as part of a pilot program using the EERPAT tool to evaluate different strategies to reduce GHG emissions in the Commonwealth. Part of the pilot program includes training MassDOT, MPOs, and regional planning agency staff in applying EERPAT to support GHG strategy analysis and policy making.

5.3 GHG IMPACTS AND COST-EFFECTIVENESS OF MPO INVESTMENTS

As discussed in section 4.2, GHG emissions can be estimated for projects in the MPO's investment programs using the travel demand model for highway and transit major infrastructure projects that meet certain capacity-adding

characteristics. The majority of capacity-adding projects funded by the MPO have been analyzed as a bundle as part of the LRTP using the travel demand model, a procedure that does not allow staff to associate a GHG reduction with a particular project. Select major infrastructure projects have been analyzed for GHG benefits if a project level analysis was performed by CTPS as part of work done for the various transportation agencies. This work used a variety of emission factors developed through older emission models. More recent work is underway; however that work was not completed in time to include it in this report.

Given the lack of availability of comparable data from the regional model, this cost-effectiveness analysis will focus on the projects that have been analyzed using the CMAQ spreadsheets described in section 4.2. The analyses included projects that were funded in the TIP under the MPO's four investment programs:

- Complete Streets
- Intersection Improvements
- Bicycle and Pedestrian
- Shuttle Bus Services (funded under the former Suburban Mobility or Clean Air and Mobility programs)

A description of other projects that do not fit into one of these investment programs is also included.

5.3.1 Roadway and Multi-Use Path Improvements

Comparing Transportation and Non-Transportation Projects

As discussed earlier, transportation is a major source of GHG emissions. Chapter 4—Promising Strategies for Reducing GHG Emissions Identified in the Literature Review, ranked strategies on their effectiveness to reduce GHG emissions. The most effective strategies include those with economy-wide pricing such as carbon taxes, congestion pricing, and pay-as-you-drive insurance; however, the MPO has no authority over implementing these strategies. The projects for which the MPO has funding authority include roadway operation, pedestrian, and bicycle improvements. The projects fall into the MPO's Complete Streets, intersection, and bicycle and pedestrian investment programs. These types of projects rank lower among the strategies reviewed in Chapter 3 but they do provide measurable GHG benefits.

Although these types of projects rank lower for GHG benefits they can, however, affect the success of other strategies, or are important for balancing equity and other needs of the transportation system as a whole. For example, if congestion pricing increases the cost of driving in order to discourage single-occupancy vehicles, there needs to be safe and comfortable alternative transportation choices available to former drivers, such as transit, walking and biking. For those

that do continue to drive, improving roadway operations, especially at intersections will help to reduce GHG emissions. Projects with lower GHG impacts can offer other significant benefits including mobility, safety, and livability.

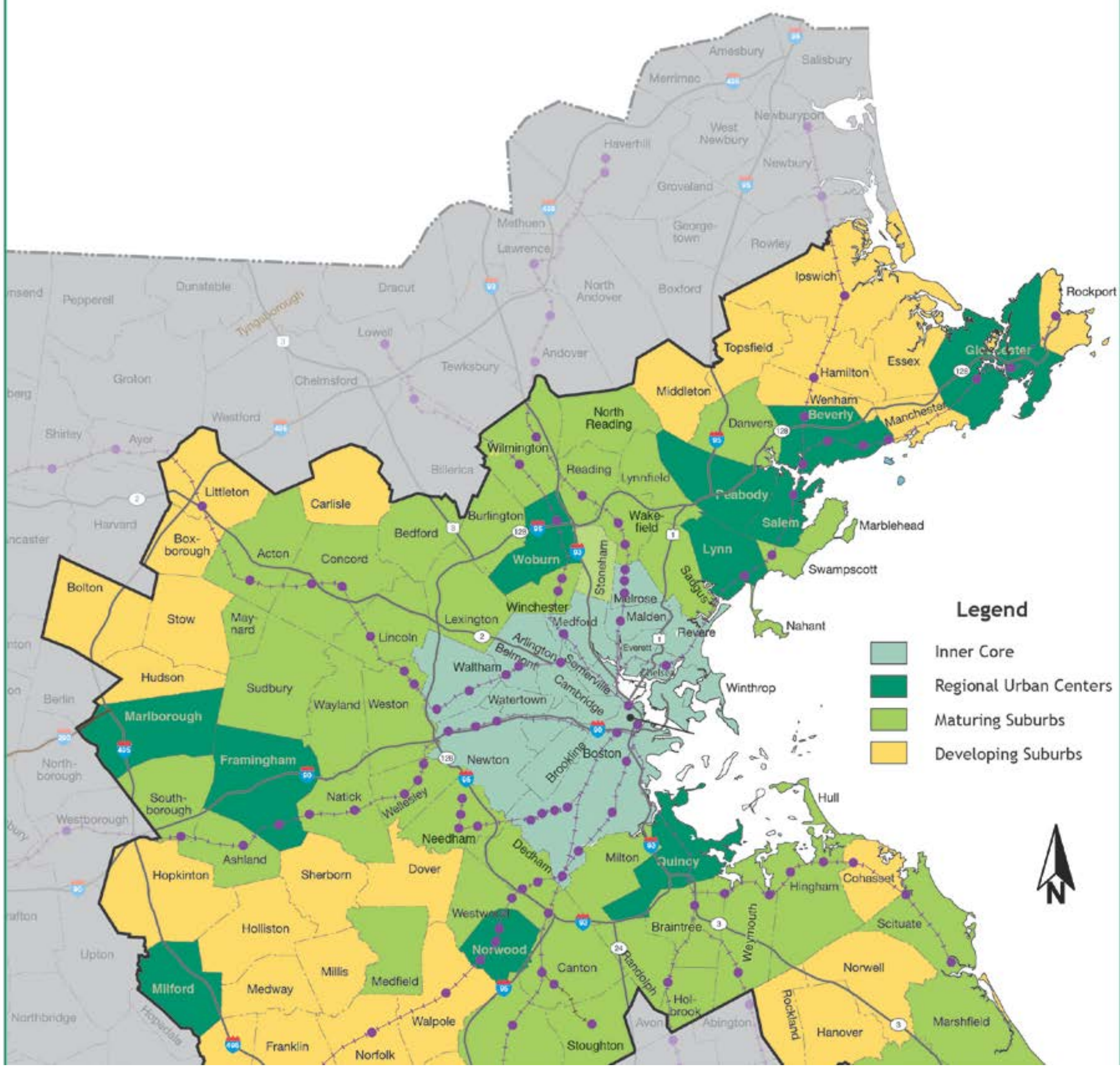
Analytical Approach

Project Comparisons by Community Type

Staff reviewed projects that were funded and/or analyzed by the MPO for their GHG benefits during the TIP development. These 51 projects are described below. The projects were distributed into the four Metropolitan Area Planning Council (MAPC) community-type groups, shown in Figure 5.1, to identify the different density and usage characteristics of the projects. MAPC classified each of the 101 municipalities in the MPO region into four community types, based on existing development patterns and growth potential.

- Inner Core: High-density built-out communities in the center of the region with multi-family homes as a significant portion of housing stock, and employment concentrated in Downtown Boston and portions of Cambridge. The Inner Core is essentially “built-out,” with little vacant developable land.
- Regional Urban Centers: Communities outside the inner core with urban-scale downtown centers, moderately dense residential neighborhoods, a mixture of built-out areas and developable land on the periphery, as well as growing immigrant populations.
- Maturing Suburbs: Moderately dense communities with less than 20 percent of land vacant and developable. These communities are comprised mainly of owner-occupied single-family homes, and are mainly residential, although some are significant employment centers.
- Developing Suburbs: Communities with large expanses of vacant developable land, ranging from those with strong town centers and moderately dense neighborhoods to ones that are more rural.

FIGURE 5.2
Metropolitan Area Planning Council
Community Types



Results by Community Type

The expected GHG reduction from a particular roadway project depends on many factors including how a roadway is used, the proposed improvement, and the amount of traffic in the area. The following information shows predicted changes in GHG emissions for 51 Complete Streets and Intersection roadway projects funded or analyzed by MPO staff.

Each roadway project is characterized by three values:

- Estimated cost of project
- Lane-miles of roadway being rebuilt or reconfigured
- Predicted annual GHG reduction in tons

From these three values, staff formed three ratios, which serve as the basis of comparison between the individual projects as well as between groups of projects defined by community type as described above. The data and ratios are shown in Table 5.1.

Within each community-type group, the projects are listed in descending order of GHG reduction per lane-mile. This column reflects how inefficiently the existing traffic within each project area is currently accommodated and the magnitude of improvement that could be expected for each proposed project. In a very few instances, the overall GHG emissions from a project are predicted to increase, and these GHG increases are reflected as negative values in the appropriate columns.

In Table 5.1, a general location is provided for each project, then three major project characteristics: estimated project cost, lane-miles of construction, and projected annual tons of GHG reduction.

The next three columns show three ratios calculated from the project characteristics:

- Cost per lane-mile
- Cost per ton of annual GHG reduction
- Tons of GHG reduction/increase per lane-mile

The extent of a proposed improvement is suggested by the number of lane-miles. These projects do not involve major bridge construction, and the cost per lane-mile roughly reflects factors such as construction difficulty, land takings, and expenses of constructing associated streetscape elements.

TABLE 5.1
Projected Greenhouse Gas Reductions
Projects Grouped by Community Type
(All Costs are in Thousands of Dollars)
(All Tons are Tons per Year)

General Location	Cost	Lane - Miles	Tons GHG	Cost per Lane-Mile	Cost per Ton	Tons per Lane-Mile
Boston - Boylston St. in Fenway	$6,555	2.52	1,963	$2,601	$3	779
Cambridge and Somerville - Beacon St.	9,088	2.20	754	4,131	12	343
Melrose - Lebanon St.	4,063	1.54	426	2,638	10	277
Arlington - Massachusetts Ave.	5,978	2.08	295	2,874	20	142
Everett - Ferry St.	6,440	3.26	458	1,975	14	140
Boston - Commonwealth Ave. near B.U.	19,180	1.96	179	9,786	107	91
Belmont and Watertown - Trapelo Rd.	13,604	5.06	314	2,689	43	62
Brookline - Brookline Village	5,070	1.56	73	3,250	69	47
Boston - 10 signal improvements	4,654	1.54	59	3,022	79	38
Newton - Walnut St.	4,648	2.54	21	1,830	-216	-8
Inner Core Group	$79,280	24.26	4,499	$3,268	$18	185
Quincy - Quincy Ave.	$1,257	0.20	602	$6,285	$2	3,009
Quincy - Hancock St.	3,891	0.14	417	27,793	9	2,975
Framingham - Route 126	8,791	1.44	924	6,105	10	642
Marlborough - Route 20 at Concord Rd.	1,707	.32	156	5,334	11	486
Lynn - Route 129 (part)	4,291	1.22	419	3,517	10	343
Lynn - Route 129 (part)	3,458	1.44	425	2,401	8	295
Marlborough - Route 85	5,144	2.28	650	2,256	8	285
Norwood Route 1A	3,275	.40	74	8,188	44	185
Beverly - Route 1A	19,874	4.08	723	4,871	27	177
Milford - Route 16	2,800	1.20	206	2,333	14	171
Quincy - Adams Green	7,911	.94	137	8,416	58	146
Woburn - Montvale Ave.	4,225	1.48	109	2,855	39	74
Salem - Canal St.	7,852	2.44	177	3,218	44	72
Marlborough - US Route 20	2,253	.60	20	3,755	112	34
Gloucester - Washington St.	4,600	2.64	30	1,742	154	11
Regional Centers Group	$81,329	20.82	5,068	$3,906	$16	243

General Location	Cost	Lane - Miles	Tons GHG	Cost per Lane-Mile	Cost per Ton	Tons per Lane-Mile
Holbrook - Weymouth St. at Pine St.	$1,017	0.20	247	$5,085	$4	1,236
Natick & Wellesley - Route 9 at Oak St.	5,810	1.86	2,146	3,124	3	1,154
Wayland - Route 27 at Route 30	2,479	0.20	226	12,395	11	1,130
Winchester - Route 3	2,014	0.74	542	2,722	4	733
Duxbury - Route 53 at Winter St.	1,107	0.20	57	5,535	20	283
Weston - Route 30 at Wellesley St.	2,429	1.06	236	2,292	10	223
Duxbury - Route 3A at Route 3	2,400	1.06	162	2,264	15	153
Southborough - Route 30	6,345	1.80	235	3,525	27	131
Lexington - Massachusetts Ave.	5,200	1.46	190	3,562	27	130
Hingham - Derby St.	3,841	3.32	388	1,157	10	117
Needham and Newton - Highland Ave.	14,298	9.15	804	1,563	18	88
Danvers - Collins St.	7,300	1.80	154	4,056	48	85
Weymouth - Libbey Industrial Pkwy.	937	0.20	15	4,685	63	74
Ashland - Route 126	13,277	3.42	155	3,882	86	45
Natick - Route 127	13,091	4.36	196	3,003	67	45
Reading - West St.	6,978	3.24	79	2,154	88	24
Hull - Atlantic Ave.	5,175	2.50	8	2,070	638	3
Holbrook - Route 139	2,471	1.74	5	1,420	547	3
Hingham - Derby St. at Route 53	2,827	0.76	-125	3,720	-23	-165
Maturing Suburbs Group	$98,996	39.07	5,721	$2,534	$17	146
Hopkinton - Route 135	7,235	1.64	1,317	4,412	5	803
Medway - Route 109	12,063	4.50	780	2,681	15	173
Walpole - Route 1A	15,886	4.66	237	3,409	67	51
Franklin - Route 140	5,120	2.54	77	2,016	66	30
Ipswich - Central and S. Main streets	2,624	1.10	5	2,385	577	4
Franklin - Pleasant St.	5,379	4.80	15	1,121	356	3
Wrentham - Route 152	3,946	1.78	2	2,217	2,294	1
Developing Suburbs Group	$52,253	21.02	2,433	$2,486	$21	116

Source: Central Transportation Planning Staff.

The cost per ton of GHG reduction varies widely, much more so than the construction cost per lane-mile. As can be observed throughout Table 5.1, the projects that substantially improve a roadway's efficiency, as reflected in the right-most column, tend also to be cost-effective with a low cost per ton of GHG reduction.

At the bottom of each group of projects are totals of the three characteristic values for each group, as well as three group average ratios. The projects within each group show a wide range of cost-effectiveness and opportunity to improve roadway efficiency. However, the group averages also exhibit some meaningful differences.

The top of Table 5.1 shows the Inner Core and Regional Centers communities. Construction costs per lane-mile are higher for these project groups than for the Maturing Suburbs and Developing Suburbs project groups shown at the bottom of Table 5.1. However, the average tons reduction per lane-mile is greater for both the Inner Core and Regional Centers than for the Maturing and Developing suburbs. Both of these differences are because of the higher density of these more urbanized communities. Higher urban density usually implies higher construction costs as well as higher traffic volumes funneling through inefficient roadway subsystems.

The higher average construction costs and efficiency benefit of the urbanized groups roughly balance out, and the average cost per ton of annual GHG reduction is similar for the Inner Core, Regional Centers, and Maturing Suburbs. The lower average cost-effectiveness in the Developing Suburbs, $21,000 per ton, may because of lower traffic volumes in these communities.

Comparing Types of Programs

All but two of the 51 projects shown in Table 5.1 would be funded through two distinct investment programs. There are 14 projects where the proposed investment is focused on the reconstruction of a specific intersection, and the characteristic values of these projects have been summed and the relevant ratios calculated, as shown in "Intersections Program" in Table 5.2.

There are 35 projects in Table 5.1 that are classified as "Complete Streets" projects, and their project totals and ratios as shown in Table 5.2. The Complete Streets projects can include one or more intersections along the improved roadway such as bicycle and pedestrian improvements. Taken altogether, these 35 projects have almost ten times the lane-miles as the 14 intersection projects.

TABLE 5.2
Projected Greenhouse Gas Reductions by Type of Investment Program
(All Costs are Thousands of Dollars)
(All Tons are Tons/Year)

Type of Program	Cost	Lane-Miles	Tons GHG	Cost per Lane-mile	Cost per Ton	Tons per Lane-Mile
Intersections	$35,804	8.88	4,813	$4,032	$7	542
Complete Streets	257,531	85.66	11,995	3,006	21	140
Multi-use Paths	41,174	21.80	1,055	1,889	39	48
All Programs	$334,509	107.46	13,050	$3,113	$26	121

Source: Central Transportation Planning Staff.

Table 5.2 also includes an analysis for a group of seven multi-use projects, not included in Table 5.1. These “multi-use paths” are used by pedestrians, bicycles, and other non-motorized vehicles. Unlike the roadway programs, GHG reductions shown for these multi-use paths do not reflect improved traffic efficiency. Instead, construction of a multi-use path is assumed to make the non-motorized modes more attractive. The annual GHG reduction shown reflects an estimate of mode shifts away from auto across these seven projects.

While costs and cost-effectiveness will vary widely within these three investment programs, the relationships of the three program averages make sense intuitively. Much of the inefficiency of regional traffic is the result of obsolete and poorly functioning intersections. Investing in only those lane-miles required to undertake the intersection program would reduce the most amount of GHG for the least cost. At the opposite extreme are the investments in multi-use paths. Most of the user benefits accrue to existing bicyclists and pedestrians, and the GHG reductions shown here are achieved only by attracting incremental users abandoning the auto mode.

The effects of roadway improvement projects on GHG emissions vary widely. It is possible, however, to compare the cost-effectiveness of roadway and multi-use path projects. Project cost and cost-effectiveness averages for the four community types are intuitively reasonable, as are the ratios developed by type of investment program. Insofar as GHG reduction is a high priority, the most important variable identified in this analysis is the GHG reduction per lane-mile, which reflects the ability of a modern roadway design to improve travel efficiency.

5.3.2 Transit Improvements

As with roadway and multi-use projects, shuttle services can affect the success of other more cost-effective GHG strategies by balancing equity and other needs of the transportation system as a whole. They can offer other significant benefits including mobility, transportation equity, and livability. The service allows people who would ordinarily drive to their destination the option to leave their car at home and use public transportation.

In the past, the MPO funded start-up shuttle-bus services under the former Suburban Mobility or Clean Air and Mobility programs through the Congestion Mitigation and Air Quality program. The CMAQ program allows funding for capital vehicle procurement and as many as three years of operations assistance for shuttle services.

Staff reviewed seven services that were funded by the MPO for their GHG reductions and cost-effectiveness. The analyses included information that was submitted at the time the proponents requested funding. The MPO's policy was to fund as much as 80 percent of the service in its first year, with the proponent paying for the remaining 20 percent. The cost-effectiveness analysis was done for projected ridership in the first year of service. The seven shuttle services, although funded since 2007, are still in operation today. However, updated information about ridership was not obtained for this study. The seven projects are shown in Table 5.3.

TABLE 5.3
Projected Greenhouse Gas Reductions from MPO-Funded Shuttle Services

Sponsor	Service	Total MPO Investment	Net CO_2 Tons/Year	Initial MPO Cost/Tons per Year
MetroWest	Route 7	$43,438	42	$1,042
MetroWest	Woodland Service	139,000	147	$947
Cape Ann Transportation Authority	Stage Fort	8,000	7	1,214
Acton	Dial-a-Ride	65,993	48	1,363
Acton	Park and Ride	52,993	94	561
GATRA	Franklin Service	175,655	30	5,852
GATRA	Marshfield/Duxbury Service	186,608	146	1,280
Combined		$671,687	514	$1,307

GATRA = Greater Attleboro-Taunton Regional Transit Authority.
Source: Central Transportation Planning Staff.

As shown in Table 5.3, the shuttle services for which the MPO provided start-up funding have a combined cost-effectiveness of $1,307 per ton of CO_2. Although updated ridership information for the services described above was not available, staff did have updated ridership information for shuttle services provided by the 128 Business Council Transportation Management Association (TMA). The 128 Business Council received a $50,000 grant under the former program for shuttle service to and from Alewife station in 1996. That proposal projected a daily VMT reduction of 1,400. The Council has expanded its services to Alewife Station and provides additional shuttles to Needham and Waltham. The current ridership for the additional service is approximately 4,500 daily riders with a corresponding CO_2 reduction of 323 tons per year. This is a good example of how an MPO investment can spark a successful service to reduce auto trips and GHG emissions.

Funding this type of service is the most cost-effective to the MPO in reducing CO_2 compared to the other three types of investments (Complete Streets, Intersections, and Bicycle/Pedestrian). This is because the sponsors continue supporting the services to realize mobility benefits that also result in significant GHG reductions.

5.3.3 GHG Reductions from Projects Statewide

MassDOT performed a GHG analysis for projects that were included in the 2013−2019 Statewide Transportation Improvement Programs grouped into similar investment programs as the investment programs used by the Boston Region MPO. The only difference was that MassDOT's calculations were done over the useful life of the project, while the MPO's analysis shows the reductions for the project's first year. The useful life for highway, bicycle, and pedestrian projects was 50 years and the useful life for transit projects was 15 years.

Table 5.4 compares statewide and MPO cost-effectiveness calculations with the projects in descending order from projects that are most cost-effective to those with a lower impact. The MPO information presented earlier in this section was revised to useful life as described above to show a comparison with the statewide results.

TABLE 5.4
Cost-Effectiveness of Statewide and MPO Investment Programs

Investment Program	Dollars of Investment (Tons per Year)	Dollars of Investment (Over the Useful Life)
MPO Shuttle Startups	$1,307	$87
MPO Intersections	7,000	140
MA. Bus Service Expansion and Bus Replacement	9,850	197
MPO Complete Streets	21,000	420
MPO Bicycle/Pedestrian	39,000	780
MA Traffic Operation improvements	43,200	864
MA Bicycle/Pedestrian	151,550	3,031

Source: Central Transportation Planning Staff.

As shown in the table, when comparing similar investment programs between the MPO and the state as a whole, the Boston Region MPO area has a lower cost per ton, which can be attributed to the higher density in the Boston region, and subsequent higher usage.

5.3.4 Other Projects that Reduce GHG Emissions

In addition to projects funded under the investment programs above, the MPO funded other projects under the former Suburban Mobility or Clean Air and Mobility programs. Many of these projects did not provide enough information to allow for a quantitative GHG analysis; however, they were deemed eligible to receive funding as part of CMAQ funding because they reduce pollutants as outlined in FHWA guidance.

A description of these projects funded by the MPO is provided below for reference purposes.

Transit Improvements

- MBTA procurement of new locomotives: Twenty new diesel electric locomotives replaced the older portion of the Commuter Rail locomotive fleet. The new locomotives produce 60 percent fewer emissions compared to locomotives in the MBTA's current fleet. The emissions savings for 20 locomotives is equivalent to taking approximately 1,077 cars off the road each day.

- MBTA procurement of switching locomotives: The MBTA switchers are stationed in rail yards to facilitate movement of rolling stock equipment—one in the north (Boston Engine Terminal) and one in the south district (Readville) of the MBTA's commuter rail system. The main function of the switchers is to move equipment throughout the yards. The MBTA purchased two new hybrid (battery pack with two small engines) switching locomotives and replaced the two older (vintage 1950s) diesel switching locomotives. The newer technology results in fewer GHG emissions.

Bicycle and Pedestrian Programs

- Boston Regional Bike Share (Hubway): The City of Boston launched its bike share system, Hubway, in August 2010 with a network of more than 50 stations, making more than 550 bicycles readily available to students, commuters, and visitors. The City of Cambridge joined the Hubway system with 14 stations, and the City of Brookline also added two stations.

  The Hubway system now provides more than 1,300 bikes at 140 stations throughout Boston, Brookline, Cambridge, and Somerville, and is continuing to add more stations. Funding from the MPO's Clean Air and Mobility Program for the City of Boston was $225,000, which funded portions of bike share expenses including warehousing, administration, information technology, and equipment maintenance. $100,000 funded expenses for supportive programs including education and safety campaigns, classes and public events, rack installation, and staffing. The City of Cambridge also applied for a Clean Air and Mobility Program grant for $228,384, which enabled Cambridge to participate in the regional Bike Share program. Brookline requested $98,308 to implement the program there.

- MBTA Bikes on Buses: The MBTA requested funding from the Clean Air and Mobility program to help meet its goal of making all buses bike accessible by 2012. The MBTA implemented a phased program of installing front-mounted bike racks on its buses. MPO funding was used to install bike racks on the remaining 310 MBTA buses so customers within the 46-community MBTA direct bus service area were assured that 100% of the MBTA vehicle bus fleet accommodated bikes. This program also will help with last mile connections.

Alternative Fuels and Vehicles

- Cambridge Clean Air Cab: This program provided an incentive to private taxicab owners to replace their existing, gas powered cabs with hybrid vehicles; it used funds provided through CMAQ to pay as much as $10,000 per vehicle to help cover the additional cost of purchasing a hybrid model vehicle.

Chapter 6—Ongoing Work and Next Steps

6.1 ONGOING WORK

In addition to the work being performed by MassDOT to identify potential new GHG emission calculation tools described above, in section 5.2, several other activities are underway at the state and MPO that will help the MPO to make decisions to fund the most cost-effective projects to reduce GHG emissions. Once completed, staff will update the MPO on outcomes of these activities, described below.

6.1.1 MPO Initiative

As discussed in section 5.1, the MPO adopted various transportation investment programs. One of the new programs is the Community Transportation/Parking/Clean Air and Mobility program. MPO staff is currently conducting a study on First-Mile and Last-Mile Transit Connections as part of the MPO's Unified Planning Work Program, as described in the next section.

First-Mile and Last-Mile Transit Connections Study

During the MPO's LRTP outreach in fall 2014, a frequent topic was ways to address first- and last-mile" connections to and from the region's transit system, particularly in suburban areas. People expressed interest in strengthening links, for example, by providing or increasing shuttle service (including expanding the frequency and hours of existing services) to link MBTA commuter rail stations and suburban communities. Because of this public interest, the MPO established a new investment program and allocated funding to a Community Transportation Investment Program. The MPO then allocated funding to a First-Mile and Last-Mile Transit Connections study to identify locations that could apply for funding allocated to this new program. This program will help reduce the number of vehicle-miles-traveled, and hence GHG emissions, by providing options to commuters and others to switch to transit rather than use their automobiles.

In this study, MPO staff would assist municipalities, Transportation Management Associations, or other service providers that requested planning support for addressing first- and last-mile connections to transit. The first phase of that study currently is underway. Candidate locations are being identified through outreach to MAPC subregions and other MPO outreach activities. For identified locations, MPO staff will document barriers and opportunities for linking residential, commercial, and employment areas to transit services and stations, and will propose services that could fill the gaps. Staff also may recommend improvements to support access for pedestrians and bicyclists, where applicable.

6.2 MassDOT Initiatives

The MPO recently adopted its LRTP, *Charting Progress to 2040*, without the benefits of a number of MassDOT initiatives. For that reason, the MPO chose not to allocate funding to major infrastructure projects in the last ten years of the LRTP planning horizon until information from ongoing activities was completed. A summary of these initiatives is provided below.

Focus40, MassDOT's Vision for MBTA's investments

MassDOT and the MBTA are in the process of developing a 25-year strategic vision for MBTA investments. This vision, Focus40, will be developed during the next year, and will engage the public as it drafts financially responsible, long-term investment strategy through 2040. It will update the MBTA's current Program for Mass Transportation (PMT). The MBTA's enabling legislation requires the Authority to update the PMT every five years and to implement the policies and priorities outlined in it through the annual Capital Investment Program (CIP).

The MPO felt it was important to have this information before determining the projects that could be funded by the MPO in later years of its planning horizon. Transit will help the MPO to achieve its Capacity Management and Mobility goal and will help in achieving its Clean Air and Clean Communities goal, specifically reducing GHG. As indicated in Chapter 4—Promising Strategies for Reducing GHG Emissions Identified in the Literature Review, transit investments could increase transit ridership and decrease the use of SOVs.

Focus40 will be developed in two phases:

1. Phase 1 will illustrate where the MBTA stands today regarding asset inventory, condition, and service performance. System-level reports will be developed for each mode of transit:
    - Buses
    - Rapid Transit
    - Commuter Rail
    - Paratransit
    - Ferry
    - Systemwide Improvements
2. Phase 2 will imagine the region that the MBTA should be planning for during the next 25 years.

Once these phases are completed, MassDOT and the MBTA will work with the public and stakeholders to develop and evaluate different investment strategies to address current and future needs.

MassDOT Capital Investment Plan

MassDOT and the MBTA are preparing five-year capital plans that will guide investments in the transportation system between 2017 and 2021. The Capital Investment Plan (CIP) will determine and prioritize investments for the next five years. It will cover all transportation projects—ranging from highway and municipal projects to regional airports, rail and transit, including the MBTA and Regional Transit Authorities, and bicycle and pedestrian projects.

Once the CIP is completed, the MPO will have information on projects and programs that the state will fund over the next five years. This will allow the MPO to consider projects that were not part of the CIP, which it may want to fund under the MPO target program to help move toward its objective of reducing GHG emissions.

6.2 NEXT STEPS

6.2.1 Implementing Strategies Outlined in the Literature Review

This report was undertaken to identify cost-effective GHG reduction strategies that can help inform MPO investment decisions. In the literature review, 23 strategies—required employer-offered compressed work week and compressed workweek: mandatory public and voluntary private are separated resulting in 24 strategies in Appendix A—were identified that fall into three categories:

- Creating a more efficient transportation system that has lower GHG emissions
- Promoting fuel efficiency and cleaner vehicles
- Coordinating transportation with land use decisions

Of these strategies, it was determined that the MPO could support 14 either through funding in the LRTP and TIP, study through the UPWP with eventual funding for implementation in the LRTP or TIP, and publicizing through public outreach. Table 6.1 shows the 23 strategies with the MPO fundable strategies in green. Strategies that the MPO could study that are not in green would require a partnership with another agency in order to implement that strategy. Also included in the table are rankings for potential GHG reductions and the average direct cost-effectiveness of strategies for which cost information was available. The rankings of the GHG and cost-effectiveness information are outlined in section 4.2 of the report.

TABLE 6.1
Twenty-Three Promising Strategies by Type, Potential MPO Role in Implementation, and GHG and Cost-Effectiveness Ranking (Based on National Data)

Category	Strategy	Strategy Type	Potential MPO Role	GHG Ranking*	Cost Ranking**
Creating a More Efficient Transportation System that Has Lower GHG Emissions	Pedestrian Improvements	Transportation System Planning, Funding, and Design	Fund or Study	14	13
	Bicycling Improvements	Transportation System Planning, Funding, and Design	Fund or Study	19	12
	Workplace Transportation Demand Management	Travel Demand Management	Fund or Study	13	9
	Teleworking	Travel Demand Management	Fund or Study	11	17
	Individualized Marketing of Transportation Services	Travel Demand Management	Fund	17	8
	Ridesharing	Travel Demand Management	Fund or Study	24	7
	Car Sharing	Travel Demand Management	Fund or Study	23	4
	Compressed Work Weeks	Travel Demand Management	Study	5/15	1
	Expansion of Urban Fixed-Guideway Transit	Transportation System Planning, Funding, and Design	Fund or Study	10	18
	Rail Freight Infrastructure	Transportation System Planning, Funding, and Design	Fund or Study	21	11
	Increased Transit Service	Transportation System Management and Operations	Fund or Study	12	19
	Transit Fare Reductions	Transportation System Management and Operations	Study	16	16

Category	Strategy	Strategy Type	Potential MPO Role	GHG Ranking*	Cost Ranking**
	Pay-As-You-Drive Insurance	Taxation and Pricing	Study or Advocate	3	6
	Vehicle-Miles-Traveled Fees	Taxation and Pricing	Study or Advocate	6	10
	Congestion Pricing	Taxation and Pricing	Study or Advocate	8	14
	Carbon Tax or Cap-and-Trade	Taxation and Pricing	Study or Advocate	1	NA
	Alternative Construction Materials	Construction Practices	Advocate	9	15
Promote Fuel Efficiency and Cleaner Vehicles	Truck-Idling Reduction	Transportation System Management and Operations	Fund or Study	18	5
	Reduced Speed Limits	Transportation System Management and Operations	Study or Advocate	7	3
	Driver Education and Eco-Driving	Public Education	Publicize	2	N/A
	Information on Vehicle Purchases	Public Education	Publicize	20	N/A
Coordinate Transportation with Land Use Decisions	Compact Development	Land Use Policies	Study or Advocate	4	2
	Parking Management	Land Use Policies	Fund or Study	22	NA

* GHG Ranking is from the most effective to least effective in reducing GHG emissions
**Cost Ranking is from the most cost-effective to the least cost-effective in reducing GHG emissions
Note: Green text indicates that a strategy can be funded by the MPO.
Source: Central Transportation Planning Staff.

As shown in the table, each category is broken down into strategy type:

1. Creating a more efficient transportation system that has lower emissions
    - Transportation System Planning, Funding, and Design
    - Transportation System Management and Operations Travel Demand Management
    - Taxation and Pricing
    - Construction Practices

2. Promoting fuel efficiency and cleaner vehicles
    - Transportation System Management and Operations
    - Public Education
3. Coordinating transportation with land use decisions
    - Land Use Policies

The majority of the strategies fall into "*creating a more efficient transportation system*" category. The pricing strategies, such as cap-and-trade or carbon tax, congestion pricing, pay-as-you-drive insurance, and VMT fees, have the most potential to reduce GHG emissions. The MPO does not have the authority to implement these programs. Thus, for these strategies, it may be appropriate to advocate for implementation to whichever local, State, or Federal body that has jurisdiction. For example, a carbon tax or cap-and-trade policy could greatly benefit greenhouse gas reduction in transportation, but would fall under national or state jurisdiction. The MPO could, however, study or advocate for the programs.

The MPO can implement a number of other strategies in this category. Infrastructure investments in transit, walking, bicycling, and rail facilities and improvements to transit service (transportation system planning, funding, and design and transportation system management and operations) are needed to strengthen low-carbon transportation choices; however, they are at the mid-to-lower end of strategies that are both GHG and cost-effective. Many of the travel demand management strategies that the MPO could fund rank lower in GHG reduction, but many are more cost-effective than the infrastructure projects. Both the infrastructure and the travel demand management strategies should not be discounted in importance because of their smaller relative potential for reductions or lower cost-effectiveness. These strategies can affect the success of others, or are important for balancing equity and other needs of the transportation system as a whole. Some of the least-cost effective strategies, namely the transit-focused strategies and teleworking, have the ability to achieve larger reductions in total; without these strategies, larger emission reductions might not be achieved. In addition, both the transit strategies and teleworking have many other benefits that support cost expenditure, in addition to GHG reduction. These strategies have important mobility and accessibility benefits.

The MPO can publicize two of the strategies that fall under the "*promoting fuel efficiency and cleaner vehicles*" category. Driver education/eco-driving can play a big part in reducing greenhouse gas emissions from transportation; however, the MPO can only publicize and promote this program for its GHG benefits. The MPO could consider seeking funding partnerships to deploy driver education or eco-driving. It also can study truck-idling reduction and potentially fund the

purchase of idle reduction equipment for trucks through its CMAQ program. The MPO could study the effects of implementing reduced speed limits, but this strategy would ultimately need to be enforced through the local and state police.

All strategies, in the "*coordinating transportation with land use decisions*" category, will require partnerships or strengthened collaboration across agencies. For instance, MAPC develops the land use plan for the region, so it is better positioned to support the compact land use strategy. Ultimately, local entities would need to implement any land use changes in their municipalities. Compact development not only has the potential to achieve the fourth-largest GHG reductions, but also could affect the strategies that the MPO can directly implement—transit infrastructure and improvements and walking and bicycle facilities. This strategy highlights the benefits of the MPO/MAPC partnership.

Partnering may be advantageous for strategies that the MPO can study. For example, MAPC has already worked with communities in the Boston region to improve parking management. The MPO may be able to use its transportation expertise to support its existing work further by coordinating with MAPC to study promising parking policies under consideration so they can be implemented by municipalities.

Another example, the workplace transportation demand management and outreach campaigns and incentives strategies could benefit and expand from the existing work of MassRIDES and transportation management associations. The MPO's new Community Transportation program can help to provide CMAQ funding for startup shuttle-service operations.

Deployment of some of the greenhouse gas reduction strategies discussed in the literature review would represent change in the MPO's historical funding patterns. The MPO may consider forging new partnerships for implementation or funding of strategies. As noted in the literature review, all the strategies could benefit from further research. Data about which strategies Massachusetts is implementing could make for better-informed decision making. Further research is needed to quantify the potential emissions reductions at the state and metropolitan regional levels.

6.2.2 Current MPO Investments

Also as part of the report, staff analyzed projects that were funded or proposed for funding in past Transportation Improvement Programs to determine their GHG cost effectiveness. The analyses included projects under four MPO investment programs:

1. Complete Streets
2. Intersection Improvements
3. Bicycle and Pedestrian Multi-Use Paths
4. Shuttle Bus Services

The current LRTP includes funding for these programs beginning in 2021 through 2040. The GHG analysis for this study and the literature review show that bicycle and pedestrian paths and bicycle and pedestrian improvements as part of Complete Streets projects are ranked low for GHG reductions. However, they can affect the success of others strategies, or are important for balancing equity and other needs of the transportation system as a whole:

- Safety – Bike lanes and protected bike lanes in particular are associated with many safety advantages, not only for people biking but also for people walking.
- Capacity management and mobility goal – by increasing the percentage of population and places of employment with access to these facilities and encourages a modal shift away from driving, decreasing VMT and therefore GHG emissions.
- Economic Vitality – These modes offer substantial vehicle cost savings; when the costs of implementation are considered together with vehicle cost saving for users supporting the economic vitality goal.
- Health – Bicycle and pedestrian facility improvements also generate benefits in terms of increased physical activity and improved public health.
- Land Use – Bicycle and pedestrian improvements, like transit, benefit compact development. These non-motorized modes support transit use by making connections to and from transit stops, and, like transit, are “much more effective” where destinations are close together in densely developed areas.

Shuttle services were not addressed in the literature review, however analysis done for this report shows that they are the most cost-effective of the four MPO investment programs for reducing GHG emissions. The MPO adopted a new funding program—Community Transportation, Parking and Clean Air and Mobility—to begin in 2021. The MPO should monitor the success of this program to ensure that enough funding is provided to promote this program for its GHG reduction potential, among other potential capacity management and mobility and economic vitality benefits.

Intersection improvements are the second most cost-effective of the MPO strategies. The analysis shows that they are projected to have a GHG reduction with an average of 542 tons per lane-mile per year. However, as outlined in the Literature Review, it should be cautioned that traffic management improvements such as intersection improvements is a strategy that reflects lower GHG emissions savings after induced demand is taken into account.

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Appendix A—Detailed Descriptions of Promising Greenhouse Gas Reduction Strategies

INTRODUCTION

This appendix provides details about each of the 24 strategies identified in Chapters 3 and 4 as being promising in their ability to reduce GHG emissions, beginning with the most effective. Each strategy includes the following details:

1. Long-Range Transportation Plan (LRTP) goals addressed by each strategy*
2. Description of the strategy
3. GHG reduction potential*
4. Cost and benefits*
5. Feasibility and timing*
6. Data needs associated with each strategy
7. MPO's role in implementing the strategy*

* More background information is provided in the following sections.

Long-Range Transportation Plan Goals

In addition to reducing GHG emissions, these strategies may address MPO goals that were established in the LRTP, *Charting Progress to 2040.* The goals addressed by each strategy are:

- Safety
- Capacity Management/Mobility
- Clean Air and Clean Communities
- Transportation Equity
- Economic Vitality
- System Preservation

Safety: Ensure that transportation by all modes will be safe by reducing the number of crashes and their severity, decreasing severe injuries and fatalities resulting from transportation, and protecting transportation users from other safety threats.

Capacity Management/Mobility: Use existing facilities' capacity more efficiently, and increase options for healthy transportation. This includes improving transit reliability, expanding and upgrading the bicycle and pedestrian network, increasing the percentages of population and places of employment

within one-quarter mile of transit stations, eliminating bottlenecks on the freight network, and emphasizing capacity management through low-cost solutions.

Clean Air and Clean Communities: Reduce greenhouse gases generated in the Boston region by all transportation modes, as outlined in the Global Warming Solutions Act, and address other environmental impacts.

Transportation Equity: Provide comparable transportation access and service quality among communities, regardless of income level or minority population. This goal incorporates targeting investments to areas that would benefit a large percentage of low-income and minority populations, and minimizing any burdens associated with MPO-funded projects in these areas.

Economic Vitality: Ensure that our transportation network provides a strong foundation for economic vitality, such as by minimizing the burden of housing and transportation costs for residents in the region, and prioritizing transportation investments consistent with the compact-growth strategies of MetroFuture, the Boston region's 30-year land use plan.

System Preservation: Ensure that the transportation system is maintained—including bridges, pavement, and transit assets—at all times, prioritize projects that support emergency response capability during extreme conditions, and protect freight infrastructure that is vulnerable to climate change impacts. The strategies included in this report do not address the system preservation goal adopted by the MPO.

Strategies' Potential to Reduce GHG Emissions

For this report, a strategy's potential to reduce greenhouse gas emissions in the transportation sector is quantified by the percent reduction in greenhouse gas emissions in 2030. This year was chosen because the primary source of information in this report was the Transportation Research Board (TRB) document, *Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process*, which examined the potential of various strategies to reduce GHG emissions compared to a 2030 baseline. Emissions impacts in 2050 are discussed in some cases where they greatly differ from 2030 impacts. The percentages provided are based on a national level of implementation, since state-wide and regional data are not widely available. On occasion, GHG reductions are expressed in terms of million metric tons carbon dioxide equivalent ($MMTCO_2e$) in addition to percentages.[1]

[1]U.S. Environmental Protection Agency, 2015, Understanding Global Warming Potentials, http://www3.epa.gov/climatechange/ghgemissions/gwps.html.

The strategies listed in this literature review were selected because they have the potential to reduce national transportation GHG emissions by at least 0.2 percent compared to the 2030 baseline. Additional GHG reduction strategies exist but are excluded from this literature review if they do not have the potential to reduce national emissions by at least 0.2 percent. A strategy is considered to have

- High GHG reduction potential if it has a maximum potential to reduce GHG by at least 1 percent
- Medium GHG reduction potential if it has a maximum potential to reduce GHG by between 0.5 and 1 percent
- Low GHG reduction potential if it has a maximum potential to reduce GHG by less than one-half percent

Although MPO staff used national emissions data in this report because of the lack of state- or region-specific data for the strategies, we caution that the relative reductions that a strategy can achieve at the national level may differ significantly at the state and regional levels.

For instance, strategies such as bicycle and pedestrian improvements may yield the greatest emissions reductions in areas with relatively higher densities of land uses, where trips between origins and destinations are relatively short. Since Massachusetts and the Boston region generally have higher population and employment densities than the rest of the country, bicycle and pedestrian improvements may be able to achieve relatively high GHG emissions reductions compared to the country as a whole.

Congestion pricing is another example of a strategy that may have a relatively higher impact on GHG emissions in the Boston region than in the nation as a whole, as this strategy can be implemented only in certain congested locations. *Moving Cooler* states that, “in the context of the regions in which congestion pricing is implemented (versus this study’s national perspective), the relative impact on GHGs will be greater”.[2]

In order to understand the effects of implementing GHG reduction strategies in the Boston region, studies are needed to develop region-specific data for each strategy. In the meantime, national data is the best information available.

The pie charts included with each of the strategies show the relative national maximum GHG reduction potential of each of the strategies relative to the maximum national potential of each of the other 23 strategies. The strategies in each pie chart are categorized by MPO role in order to compare each strategy with other strategies that have the same MPO role. Strategies that the MPO can

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[2] Cambridge Systematics Inc., 2009, *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*, Urban Land Institute, p. 40.

fund are shown in light green; those that the MPO can publicize are in olive-green; and those that the MPO can only study or advocate are shown in dark green.

Cost and Benefits

Strategy Cost-Effectiveness

Each strategy's cost-effectiveness is quantified in terms of the direct cost to the implementing agency per $MTCO_2e$ reduced. This report discusses cost-effectiveness based on a national level of implementation. In addition, when available, a strategy's cost or savings to the public are also provided because many strategies have been found to save the public money.

For comparative purposes, we divided strategies into high, medium, and low cost-effectiveness:

- **High Cost-effectiveness**: Cost less than $250 per $MTCO_2e$ reduced
- **Medium Cost-effectiveness**: Cost between $250 and $500 per $MTCO_2e$ reduced
- **Low Cost-effectiveness**: Cost more than $500 per $MTCO_2e$ reduced

These categories were informed by the *Incorporating Greenhouse Gas Emissions* report by the Transportation Research Board, which quantifies direct implementation costs.[3]

There also is uncertainty surrounding the cost-effectiveness estimates of many strategies because of the limited studies on cost-effectiveness. Furthermore, the cost-effectiveness of an approach can differ considerably by location (e.g., rural versus urban) and context. The Transportation Research Board cautions against drawing blanket conclusions.[4] It recommends that strategies with substantial GHG reduction potential not be ruled out based on cost alone without analyzing the local region or by viewing them as part of a larger set of pricing strategies, some of which could provide revenue to support others that are more costly.

Other Strategy Benefits

In addition to emissions-reduction potential and cost-effectiveness, other considerations are important when selecting strategies for implementation. While cost-effectiveness is primarily discussed in this literature review in terms of direct implementation costs, the Transportation Research Board (and Cambridge

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[3] Transportation Research Board, *Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process*, 2013 Strategic Highway Research Program (SHRP 2), Report S2-C09-RR-1, p. 33.

[4] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 33.

Systematics) cautions against neglecting other perspectives and inaccurately representing full social costs and benefits,[5] such as:

- Travel time savings
- Other welfare gains or losses (because of accessibility and increased or decreased convenience)
- Equity (incidence of costs and benefits across population groups)

Resources such as *Moving Cooler* (Cambridge Systematics) and *Transportation's Role* (Cambridge Systematics and Eastern Research Group) quantify net costs (e.g., including vehicle operating savings) when discussing cost-effectiveness, demonstrating the prevalence of this methodology. However, they both highlight the need to consider further social costs and benefits. For example, while transit expansion and other major infrastructure improvements are not directly cost effective, they can be worthwhile for other purposes such as mobility, safety, and livability. They can also support a package of strategies that is collectively more cost effective, such as when transit is paired with compact development.[6]

Information about costs and benefits is included for each strategy. Equity impacts can vary from strategy to strategy. Disproportionate impacts (such as those related to pricing) on particular groups may need to be balanced or addressed. For example, lower-income groups already spend as much as four times more of their income on transportation compared to higher-income groups.[7] Social concerns, highlighted in FHWA's *Reference Sourcebook for Reducing Greenhouse Gas Emissions from Transportation Sources*, considers public perception of strategies. Unique benefits and unique negative effects include impacts on livability, safety, and the environment.

Feasibility and Timing

The implementation feasibility rankings for technical, institutional, and political categories are listed as suggested in the Transportation Research Board's 2013 report, *Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process*. These ratings refer to the feasibility of implementation on a national scale, and may differ for Massachusetts or for the Boston region. Implementation concerns may include the need for inter-agency coordination. The U.S. Department of Transportation's Report to Congress, titled *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions* was a

[5] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 32-33.

[6] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 33.

[7] Cambridge Systematics, *Moving Cooler*, p. 83.

central reference for information about timing of benefits (short, medium, or long), and asked the following questions for each strategy:

- **Technical Feasibility**: Is the technology well developed and proven in practice? What is the likelihood that the technology could be implemented in the near future at the deployment levels assumed in the analysis? Technological barriers can be low-tech as well as high-tech (for example, there may be right-of-way constraints to infrastructure expansion in urban areas).
- **Institutional Feasibility**: To what extent do the authority and resources exist for government agencies to implement the strategy? What is the administrative ease of running a program; and what are the levels of coordination required among various stakeholders?
- **Political Feasibility**: Is the strategy generally popular or unpopular with any interested stakeholders, elected officials, and the general public? What is the political influence of those supporting versus those opposed to the strategy?

Feasibility is assessed without respect to cost, which was evaluated as part of the cost-effectiveness measure.

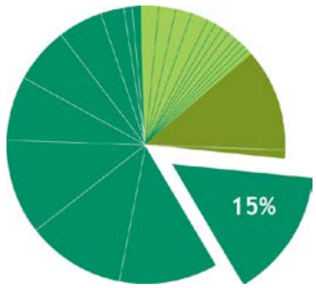
MPO Role in Implementing the Strategy

The strategies in each pie chart are categorized by MPO role to allow comparison of each strategy with other strategies that have the same MPO role:

- Light green – strategies that the MPO can fund
- Olive green – strategies that the MPO can publicize
- Dark green – strategies for which the MPO can only study or advocate

PROMISING STRATEGIES

1) Carbon Tax or Cap-and-Trade



Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	NA
Technical Feasibility	M
Institutional Feasibility	M
Political Feasibility	L-M
MPO Role	Study or Advocate

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities

Description:

A carbon tax or cap-and-trade policy, the most effective strategy for reducing GHG emissions, works by putting an economy-wide price on carbon (CO_2e). Pricing carbon is a market-based way to reflect the externalities, or greater social costs, of climate change. This strategy increases the cost of carbon-intensive decisions, providing businesses and consumers with the incentive to make less carbon-intensive transportation decisions. A carbon tax works by "rais[ing] the price of fossil fuels, with more taxes collected on fuels that generate more emissions."[8] Under a cap-and-trade program, the government sets a cap on the level of emissions, and creates allowances for emissions up to the level of the cap. Entities that are sources of carbon emissions can buy or sell these allowances.[9] Carbon pricing legislation could be adopted at the state or national level.

GHG Reduction:

Projections for national GHG emissions reductions range from 2.8 percent to 4.8 percent below the national transportation baseline in 2030.[10] This great potential for reductions assumes a substantial level of pricing with an allowance price of

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[8] The Editorial Board, The Case for a Carbon Tax, 2015, *The New York Times*, http://www.nytimes.com/2015/06/07/opinion/the-case-for-a-carbon-tax.html (accessed December 15, 2015).

[9] U.S. Environmental Protection Agency, Cap and Trade 101, 2015, http://www.epa.gov/capandtrade/captrade-101.html (accessed December 15, 2015).

[10] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 25.

$30 to $50 per $MTCO_2$ in 2030 or a similar carbon tax.[11] A carbon tax or cap-and-trade policy would achieve greater GHG cuts than other pricing strategies such as pay-as-you-drive (PAYD) and a vehicle miles traveled (VMT) fee, because directly pricing carbon encourages important improvements in fuel economy through utilizing more fuel-efficient vehicles and encouraging decreases in VMT.[12]

According to Cambridge Systematics and Eastern Research Group's 2010 report to Congress, one key difference between a cap-and-trade system and a carbon tax is that a carbon tax offers more certainty regarding energy prices, while a cap-and-trade system offers more certainty regarding overall GHG levels. Both policies are intended to shift activities to less GHG-intensive alternatives such as purchasing more fuel-efficient vehicles, using lower carbon fuels, taking public transportation, walking, biking, telecommuting, carpooling, and compact development.[13]

Costs and Benefits:

The Transportation Research Board (2013) analysis does not contain cost estimates. However, the estimates in *Moving Cooler* (2009) suggest relatively cost-effective implementation for carbon pricing compared to other pricing strategies—more than three times smaller than the cost of implementing a VMT fee, for instance.[14] Costs may be administrative in nature. A carbon tax may have an implementation advantage of a reduced administrative burden compared to a cap-and-trade program.[15]

Carbon pricing and other strategies that encourage a shift from single-occupancy vehicles to more efficient transportation modes also may help with the MPO's capacity management and mobility goal.

All pricing strategies, including carbon tax and cap-and-trade, would negatively affect lower-income groups unless mitigated. These groups "spend a higher proportion of their income on transportation, are less able to afford to pay higher fees, and may be priced off these services altogether."[16] Both a carbon tax and a

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[11] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 25.

[12] Cambridge Systematics Inc., *Moving Cooler*, p. 40.

[13] Cambridge Systematics, Inc. and Eastern Research Group, Inc., 2010. *Transportation's Role in Role in Reducing U.S. Greenhouse Gas Emissions*, Volume I, Report to Congress., U.S. Department of Transportation, Washington, D.C., pp. 4-28.

[14] Cambridge Systematics, *Moving Cooler*, p. 41.

[15] Cambridge Systematics, Inc. and Eastern Research Group, Inc., *Transportation's Role*, pp. 4-27.

[16] Cambridge Systematics Inc., *Moving Cooler*, p. 73.

cap-and-trade system could be made more socially equitable by providing rebates to low-income households for a carbon tax or compensating low-income households with some of the revenue generated through the cap-and-trade system. These policies could also create a new or alternative revenue source (depending on the amount of revenue distributed in rebates) that could be used to fund transportation infrastructure.[17] Investing in transportation services such as public transit may also help to mitigate adverse equity impacts.[18]

Feasibility and Timing:

The Transportation Research Board rates these policies' feasibility for nationwide implementation as medium technically and institutionally, and low to medium politically. Of all the taxation and pricing strategies examined in this literature review, cap-and-trade and carbon tax have the greatest technical feasibility. Carbon pricing is based on fuel/energy usage, which currently is well tracked. This is in contrast to distance traveled, upon which other pricing strategies are based, but which is not already systematically documented.[19]

Massachusetts is already part of a regional cap-and-trade initiative to reduce CO_2 emissions from power plants. The Regional Greenhouse Gas Initiative (RGGI) is a cooperative program among Connecticut, Delaware, Maine Maryland, New Hampshire, New York, Rhode Island, and Vermont that was implemented in 2008. To date, programs funded by cumulative RGGI investments have saved participating households $395 million and cut emissions by 1.2 $MMTCO_2$.[20]

A draft of bill S.1747, *An Act Combating Climate Change*, was introduced in fall 2015 that shows how Massachusetts could adopt a price on carbon. The act's purpose is to levy fees on fuels that emit CO_2, driving energy demand and emissions down. The act would distribute proceeds of the fee to residents equally via a rebate, thereby avoiding raising taxes. Residents who use more energy than average would pay more in fees than they receive in rebates. Most residents (the bottom 60 percent) are projected to receive rebates. A fee would be set at $10 per ton of CO_2 in the first year and increase by $5 per ton each year until it reaches $40 per ton seven years after adoption of the program.[21,22]

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[17] Cambridge Systematics, Inc. and Eastern Research Group, Inc., *Transportation's Role*, p. 4-28.

[18] Cambridge Systematics Inc., *Moving Cooler*, p. 73.

[19] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 25.

[20] RGGI Inc., *Regional Greenhouse Gas Initiative*, http://www.rggi.org/ (accessed December 15, 2015).

[21] Senator Mike Barrett, An Act Combating Climate Change: The Basics, 2015, http://senatormikebarrett.com/wp-content/uploads/2015/10/Carbon-Pricing-the-basics.pdf (accessed November 5, 2015).

The timing of this strategy's benefits extends over the short to long term, from within five years to more than twenty years.[23] This means that this strategy potentially could achieve strong immediate effects if sufficiently high pricing is in place, and even greater long-term effects as transportation system users, fuel providers, and vehicle manufacturers respond by making more structural adjustments.[24]

Data Needs:

No Massachusetts or Boston MPO-specific data is available for transportation sector GHG reductions or cost-effectiveness of various policies that support this strategy.

MPO Role:

The MPO does not have the authority to implement cap-and-trade or a carbon tax. If requested, the MPO could study the transportation benefits or advocate on behalf of this strategy. State agencies could, in turn, implement this policy at the state level (such as through Senate bill 1747) and/or seek implementation at the national level.

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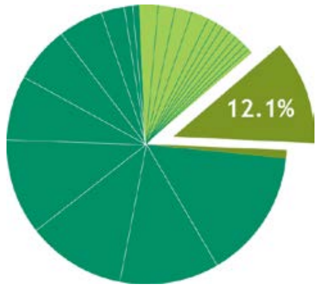
[22] The 189th General Court of Massachusetts, Bill S.1747, 2015, https://malegislature.gov/Bills/189/Senate/S1747 (accessed November 5, 2015).

[23] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-33.

[24] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 4-13.

2) Driver Education and Eco-Driving



Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	H
Technical Feasibility	L
Institutional Feasibility	L
Political Feasibility	H
MPO Role	Publicize

LRTP Goals Addressed:

- Safety
- Clean Air/Clean Communities
- Economic Vitality

Description:

Driver education, also known as eco-driving, consists of small changes in driving behavior—such as gentler braking and acceleration, slower driving, improved vehicle maintenance, and avoided idling—that collectively improve fuel economy. These practices can be encouraged through educational campaigns, in-vehicle training programs, and "dynamic eco-driving," where in-vehicle or road-based sensors provide drivers with feedback about their behaviors and emissions.[25] Driver education has the second-greatest potential to reduce GHG of the strategies studied in this literature review, along with potential cost-effectiveness.

GHG Reduction:

If driver education reaches 10 to 50 percent of the population, and in-vehicle instrumentation is provided, national transportation GHG emissions potentially could decrease by 0.8 to 3.7 percent. Specifically, Cambridge Systematics' analysis in *Moving Cooler* (2009) suggests potential reductions of 0.8 to 2.3 percent and the International Energy Agency (2005) predicts a 3.7 percent reduction.[26] According to *Moving Cooler*, implementing this strategy could

[25] U.S. Department of Transportation, Federal Highway Administration, *Reference Sourcebook for Reducing Greenhouse Gas Emissions from Transportation Sources*, 2012, by Rand Corporation and RSG, Inc., http://www.fhwa.dot.gov/environment/climate_change/mitigation/publications_and_tools/reference_sourcebook/referencesourcebook.pdf (accessed March 6, 2014), p. 201.

[26] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

generate results in the near term,[27] which would benefit cumulative savings over the long term as well.

Drivers who take in-vehicle eco-driving courses typically experience a 10 to 15 percent reduction in fuel consumption, and achieve better fuel economy than conventional drivers achieve, even two years after completing the course.[28]

A University of California study found that a 10 to 20 percent reduction in fuel use might be achieved through dynamic eco-driving technology, without much impact on travel time. (The researchers also noted that more savings were achieved in conditions with greater congestion.)[29] Some vehicles already include in-vehicle eco-driving instrumentation, and after-market instrumentation is available as well. Examples of vehicles with in-vehicle technologies include Ford's Fusion and Milan hybrid models, Honda's Insight model, Kia models with automatic transmission, and certain Toyota models. PLX Devices' Kiwi after-market miles-per-gallon meter is compatible with vehicles built in 1996 or later, and Hunter Research and Technology's inexpensive greenMeter application for iPhone and iPod Touch likewise could be used by drivers of vehicles without existing instrumentation.[30]

Costs and Benefits:

Cost estimates are not available for this strategy. However, it was included in *Moving Cooler's* "Low Cost" bundle of strategies, signifying low net costs when direct implementation costs are balanced with driver savings. One estimate cited by FHWA (2012) suggests costs for educational programs could be as low as \$14 per $MTCO_2$, signifying high cost-effectiveness: "In theory, eco-driving campaigns (e.g., formal public education and outreach on the nature and benefits of eco-driving) and programs may be among the more cost-effective ways to address GHG emissions." However, the cost-effectiveness of training only or dynamic technology is not currently known.[31]

Driver education and eco-driving may address the LRPT goals of safety, clean air and clean communities, and economic vitality. Potential safety benefits are

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[27] Cambridge Systematics, Moving Cooler, p. 42.

[28] Mineta Transportation Institute, *Ecodriving and Carbon Footprint: Understanding How Public Education Can Reduce Greenhouse Gas Emissions and Fuel Use*, 2012, by Susan A. Shaheen, Elliot W. Martin, and Rachel S. Finson, M.A., http://tsrc.berkeley.edu/sites/tsrc.berkeley.edu/files/ecodriving-greenhouse-gas-emissions-fuel-use-public-education.pdf (accessed March 24, 2014), p. 24.

[29] Mineta Transportation Institute, *Ecodriving and Carbon Footprint*, p. 15.

[30] Mineta Transportation Institute, *Ecodriving and Carbon Footprint*, pp. 21-22.

[31] USDOT, FHWA, *Reference Sourcebook*, p. 204.

associated with less aggressive driving.[32] Smoother driving patterns and improved vehicle maintenance reduce air pollution.[33] In addition, this strategy has one of the greatest positive impacts on vehicle costs, and saves drivers money.[34] The Michigan Action Council and Center for Climate Strategies estimate that an eco-driver program that trains 3 percent of Michigan's population annually will have a negative net cost-effectiveness of -$211 per $MTCO_2e$ by 2030 because of drivers' fuel savings. The MPO's economic vitality goal is addressed by these cost savings for consumers.[35]

Feasibility and Timing:

Eco-driving voluntary training programs have been implemented in other countries such as Belgium, Iceland, Norway, Spain, and the United Kingdom.[36] In the US, a pilot eco-driving program is underway in the San Francisco Bay Area and some commercial fleet operators (e.g., United Parcel Service and Staples) include eco-driving in their employee training and equipment.[37]

The Transportation Research Board considers this strategy to have high political feasibility and FHWA reports "no significant barriers to implementing eco-driving…" and predicts high social acceptability.[38] Nevertheless, the TRB's low ratings for technical and institutional feasibility suggest that there may some challenges for national implementation.[39] The technical challenges are based on the strategy's assumptions regarding widespread adoption of in-vehicle instrumentation.[40] Promoting eco-driving is a MassDOT GreenDOT goal.[41]

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[32] USDOT, FHWA, *Reference Sourcebook for Reducing Greenhouse Gas Emissions from Transportation Sources*, 2012, Rand Corporation and RSG, Inc., FHWA Project DTHF61-09-F-00117, pp. 201-205.

[33] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp.5-101.

[34] Cambridge Systematics, *Moving Cooler*, p. 42.

[35] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp.5-100.

[36] Cambridge Systematics, *Moving Cooler*, p. 42.

[37] Cambridge Systematics, n.d. What Are the Most Effective Things a State or Regional Transportation Agency Can Do to Reduce Greenhouse Gas Emissions, and Support Energy Independence, http://www.camsys.com/kb_experts_enviro.htm (accessed December 15, 2015).

[38] USDOT, FHWA, *Reference Sourcebook*, pp. 201-205.

[39] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[40] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-37.

[41] Massachusetts Department of Transportation, *GreenDOT Implementation Plan*, 2012, https://www.massdot.state.ma.us/GreenDOT/GreenDOTReport/GreenDOTImplementationPlan.aspx (accessed December 15, 2015).

Most eco-driving benefits could be realized in the short to mid-term, from within five years to less-than twenty years.[42]

Data Needs:

Unfortunately, the long-term effects of eco-driving campaigns and dynamic eco-driving are still largely unknown because “few [campaigns] have been studied rigorously, despite some evidence that [eco-driving] is one of the most cost-effective ways to reduce GHG.”[43] The level of interest from Consumers interest in the strategy of eco-driving has not been determined.[44] In addition, air-pollutant-emission reductions have not been quantified.[45]

No Massachusetts or Boston MPO data is available for GHG reductions associated with eco-driving/driving education. Updated projections for the state and Boston region are not available. Limited data is available on the cost-effectiveness of this strategy.

MPO Role:

No campaigns or programs exist in Massachusetts to date, however MassRIDES includes eco-driving tips on their website as part of a *Drive Smart and Save* program. The MPO potentially could provide funding support for a program if one is established by another agency or organization. It could be funded through the MPO’s Clean Air and Mobility program using Congestion Mitigation and Air Quality (CMAQ) funds, if approved by the Federal Highway Administration (as an innovative project). Alternatively, it could provide information about such a program through its public-information channels.

Eco-driving has the second-greatest potential to reduce GHG emissions of all the strategies, and the greatest potential for emissions reductions of the strategies that the MPO can fund (although the MPO is limited in funding only certain aspects of the program).

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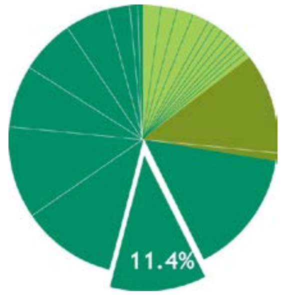
[42] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, pp. 3-37.

[43] USDOT, FHWA, *Reference Sourcebook*, p. 201.

[44] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, Volume 2, pp.5-101.

[45] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, Volume 2, pp.5-101.

3) Pay-as-You-Drive Insurance



Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	H
Technical Feasibility	L-M
Institutional Feasibility	L-M
Political Feasibility	M
MPO Role	Study or Advocate

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Transportation Equity
- Economic Vitality

Description:

The third most-promising strategy in terms of the greatest potential to reduce GHGs is pay-as-you-drive insurance. This strategy charges drivers for vehicle insurance based on their vehicle-miles-traveled. Individuals' VMT data may be collected without compromising their privacy via audited odometer readings, advanced electronics, global positioning systems, and other telematics technologies. As users are informed of the insurance costs that they are paying on a per-mile basis, they are prompted to travel by vehicle less in order to reduce their costs. With PAYD, some of the fixed costs of owning a vehicle are changed to variable costs that may be managed by driving less.[46] PAYD would reduce costs for the majority of travelers and has high cost-effectiveness for the implementing agency.[47]

GHG Reduction:

PAYD is estimated to provide national GHG reductions of 1.1 to 3.5 percent annually. The low end of the reductions range may be achieved by requiring states to permit PAYD; and the high end of the range is possible by requiring motor vehicle insurance companies to offer PAYD.[48]

Costs and Benefits:

At a direct cost of \$30 to \$90 per $MTCO_2$, this strategy is highly cost-effective.

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[46] Cambridge Systematics, *Moving Cooler*, pp. 70-71.

[47] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-18.

[48] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 25.

PAYD could have beneficial transportation equity effects if implemented, addressing this LRTP goal. A Massachusetts Institute of Technology (MIT) study concluded that tying insurance rates to VMT would improve fairness among drivers because accident costs are related to miles driven. In addition, lower-income households drive less than higher-income households do; and a nationwide study by the Brookings Institute found that lower-income households generally would save money with PAYD, and that on average, higher-income households would pay more.[49]

Cost savings to consumers via this strategy may support the MPO's economic vitality goal. Large vehicle operating cost savings would result in a negative net cost-effectiveness of -\$900 per $MTCO_2e$. Two-thirds of households are projected to see lower auto insurance premiums with PAYD (premiums would increase for the remaining one-third).[50]

PAYD also may help with the LRTP goals of capacity management/mobility and clean air/clean communities, as it encourages a decrease in VMT. In general, transportation demand-management strategies such as PAYD "address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[51]

This pricing strategy would not promote fuel-efficiency gains unless the VMT fees also were tied to vehicles' GHG emission rates, fuel efficiency, or weights. PAYD (and VMT fee) technology also could be used to support congestion pricing, which would promote improved capacity management/mobility and reduced travel times.[52]

Feasibility and Timing:

In Massachusetts, PAYD was selected as a strategy to meet the Global Warming Solutions Acts goals, but has encountered considerable implementation challenges. The Massachusetts Executive Office of Energy and Environmental Affairs' December 2013 Global Warming Solutions Act progress report notes that this strategy has made "low" progress, and that a PAYD Auto Insurance Pilot funded by a FHWA grant is currently stalled: "The Commonwealth's plan to first initiate a pilot program, which could then be transitioned into a broader program,

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[49] Ian A. Bowles, *Massachusetts Clean Energy and Climate Plan for 2020* (2010), http://www.mass.gov/eea/docs/eea/energy/2020-clean-energy-plan.pdf (accessed February 25, 2015), p. 62.

[50] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 5-23.

[51] USDOT, FHWA, *Reference Sourcebook*, p. 31.

[52] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-25.

is delayed due to potential legal challenges. Without a successful pilot program, it will be challenging to fine-tune and deploy a broader PAYD program that is effective at reducing VMT while also addressing the needs of insurers and consumers." Furthermore, the progress report questions the initial estimates of 0.4 to 2.1 percent statewide GHG reductions (from 1990 levels) achieved with full implementation. [53]

Nationally, the Transportation Research Board considers this strategy to have low-to-medium technical and institutional feasibility and medium political feasibility. This strategy has the highest political feasibility of the taxation and pricing-based strategies considered in this literature review.[54] PAYD has had consumer satisfaction rates as high as 87 percent when implemented, with the potential to save money compelling most people to reduce VMT. In addition, because signing is voluntary with this strategy, individuals who do not wish to have PAYD can simply choose not to.[55] PAYD insurance is currently offered in 35 states and is a MassDOT GreenDOT goal.[56, 57]

After implementation, the timing of benefits for PAYD is short term; the majority of GHG reductions can be achieved without delay.[58]

Data Needs:

The Massachusetts Executive Office of Energy and Environmental Affairs' Global Warming Solutions Act progress report cited above raised uncertainty about initial projections for GHG reductions attainable with this strategy in Massachusetts.[59] No updated Massachusetts or Boston MPO data is available about the GHG reductions associated with a PAYD Insurance strategy.

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[53] Massachusetts Executive Office of Energy & Environmental Affairs, Global Warming Solutions Act Implementation Subcommittees, *Global Warming Solutions Act: 5-Year Progress Report*, 2013, http://www.mass.gov/eea/docs/eea/gwsa/ma-gwsa-5yr-progress-report-1-6-14.pdf (accessed February 25, 2015), p. 56.

[54] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[55] USDOT, FHWA, *Reference Sourcebook*, pp. 64-65.

[56] http://www.lowmileagediscount.com/what-is-payg/lmd-states.asp.

[57] Massachusetts Department of Transportation, *GreenDOT Implementation Plan*, 2012, https://www.massdot.state.ma.us/GreenDOT/GreenDOTReport/GreenDOTImplementationPlan.aspx (accessed December 15, 2015).

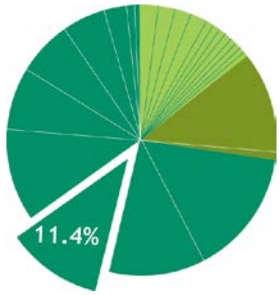
[58] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

[59] Massachusetts Executive Office of Energy and Environmental Affairs, Global Warming Solutions Act Implementation Subcommittees, *Global Warming Solutions Act: 5-Year Progress Report*, p. 56.

MPO Role:

The MPO does not have the authority to implement PAYD Insurance. Depending on the outcomes of the Massachusetts PAYD pilot program legal challenges, this strategy may move forward in Massachusetts. If requested, the MPO could study or advocate for the transportation benefits of this strategy.

4) Compact Development



Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	H
Technical Feasibility	M
Institutional Feasibility	L
Political Feasibility	L
MPO Role	Study or Advocate

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Transportation Equity
- Economic Vitality

Description:

Compact development can reduce the need for travel because destinations and activities are in close proximity. Utilizing land use codes, regulations and policies to attain compact development could have as great a potential impact on GHG emissions as a pay-as-you-drive insurance policy, and would be highly cost-effective.

GHG Reduction:

Cambridge Systematics estimates that between 0.2 to 1.8 percent GHG reductions are possible if 60 to 90 percent of new urban growth occurs in compact, walkable neighborhoods (+4,000 persons per square mile or +5 gross units per acre). Another analysis suggests cuts of between 0.4 to 3.5 percent if 25 to 75 percent of new urban growth occurs in compact, mixed-use developments.[60] The potential for high GHG reductions is backed by studies that have estimated that VMT can be cut by 5 to 12 percent if a region doubles its residential density and that GHG emissions can be reduced 7 to 10 percent in 2050 from current trends if 60 percent of new US residential growth follows compact patterns.[61] Overall, low-density development has been found to result in twice the GHG emissions per capita as high-density development.[62]

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[60] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[61] USDOT, FHWA, *Reference Sourcebook*, p. 25.

[62] U.S. Environmental Protection Agency, *Smart Growth: A Guide to Developing and Implementing Greenhouse Gas Reductions Programs*, 2011,

Costs and Benefits:

The estimated direct cost of this strategy for the implementing agency is only $10 per $MTCO_2$; compact development is highly cost-effective.[63] In addition, compact development saves municipalities money. A study by the Sacramento Area Council of Governments found that infrastructure costs an average of $20,000 less per housing unit for compact development than for low-density areas.[64]

According to *Moving Cooler*, land use and smart growth can provide an option to offset negative equity impacts of other GHG reduction strategies that cause increased transportation costs. By improving accessibility and mobility for individuals without access to automobiles and avoiding increased costs of automobile travel, compact development benefits multiple groups, addressing the transportation equity and capacity management/mobility LRTP goals. Other potential concerns regarding the effects of possible increases in property values may be mitigated by decreased transportation costs.[65] Nevertheless, policies to preserve housing affordability could ensure that the benefits of improved access are available equitably.

Feasibility and Timing:

Nationally, market and demographics trends are shifting towards more compact development patterns. The demand for compact development—attached and small-lot detached—was estimated at 46 percent of the national market in 2006 and could increase to 60 percent in 2025. Local zoning regulations that prevent higher density, mixed-use development have caused “an apparent undersupply” of this type of development. Other obstacles contributing to the undersupply include street designs that prioritize motorized travel at the expense of other modes and minimum parking requirements. As Cambridge Systematics and Eastern Research Group conclude, these trends may indicate that “some level of land use change likely would be supported by market factors; but more significant change approaching the more aggressive levels” such as those put forth in *Moving Cooler* “is likely to require stronger policy intervention.”[66]

Perhaps because of this need for stronger policy intervention, the Transportation Research Board predicts future institutional and political challenges at the national level, ranking these areas low feasibility. Technical feasibility is ranked

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http://www.epa.gov/statelocalclimate/documents/pdf/sm_growth_guide.pdf (accessed March 20, 2015).

[63] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[64] Urban Land Institute, *Growing Cooler*, p. 147.

[65] Cambridge Systematics Inc., *Moving Cooler*, pp. 73-74.

[66] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, pp. 5-69–5-70.

medium.[67] As with all the strategies, feasibility may be different in Massachusetts than it is at the national scale. Massachusetts and the Boston region already are more densely settled than many areas of the country.[68]

Most of the benefits of compact development would not be realized within the first twenty years.[69] This strategy is best poised to help meet the statewide Global Warming Solutions Act limit for 2050.

Data Needs:

No Massachusetts or Boston-region-specific data quantifying GHG reductions achievable through compact development are available at this time.

MPO Role:

Growing Cooler provides examples of regional policy recommendations that can encourage compact development: regional transfer of development rights (TDR) programs, carbon impact fees for new development, and assistance to local governments with land development reforms. The MPO cannot directly fund land-use programs to encourage compact development. However, using its new land-use model, the MPO, in conjunction with MAPC, could study land-use policies that have direct links to transportation. For example, over the past several years, MAPC has conducted research and provided technical assistance to encourage transit-oriented development (TOD) near MBTA station areas.

The MPO also could advocate for particular types of land use policies that have benefits for the transportation system and for GHG reductions. For example, carbon impact fees for new development internalize carbon impacts into development costs, similar to more conventional impact fees that governments have charged to offset the costs of new development on transportation, schools, etc. This policy would reward best development practices, including compact, mixed-use development, and revenues could be put towards funding transit, bicycle, and pedestrian facilities. The San Joaquin Valley Air Pollution Control District in the Fresno, California area provides an example of an emissions-based development impact fee. In 2006-07, the district spent more than $9.5 million of nearly $13 million collected in emissions-reduction projects fees that reduced nitrogen oxide pollution by 824 tons and particulate matter (as much as 10 microns in diameter) by 34 tons.[70]

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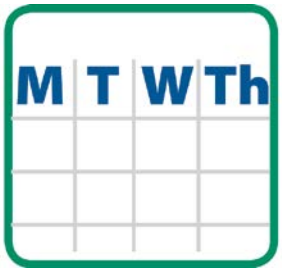
[67] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

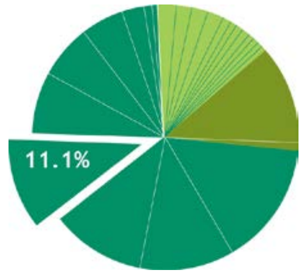
[68] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

[69] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

[70] Urban Land Institute, *Growing Cooler*, pp. 148-149.

5) Required Employer-Offered Compressed Work Week





Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	H
Technical Feasibility	H
Institutional Feasibility	L
Political Feasibility	L-H
MPO Role	Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities

Description:

Compressed workweeks save GHG emissions by reducing the number of days that employees need to commute to their workplaces and the total weekly VMT. Examples of compressed workweeks include a four-day, 40-hour schedule (one less day of commuting per week) and a nine-day, 80-hour schedule (one less day of commuting per two weeks). As long as employees drive less on their day off than they would have done on a workday, there would be a reduction in VMT and GHG emissions.

GHG Reduction:

If employers were required to offer the option of working a compressed four-day, 40-hour work week to employees whose jobs are amenable, the International Energy Agency calculated that a sizable GHG emissions reduction of 2.4 percent could be achieved. In this scenario, employees choose whether they would like to adopt a compressed schedule; however, it is assumed that not all employees would choose to adopt a compressed schedule when offered.[71]

Costs and Benefits:

A requirement to offer a compressed work week would be extremely cost-effective, with less than $1 per $MTCO_2e$ in direct public sector costs.[72]

This strategy may support the Long-Rang Transportation Plan goals of capacity management/mobility and clean air/clean communities, as it decreases overall VMT, which in turn, would result in air quality benefits.

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[71] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[72] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

Data Needs:

No studies have been conducted about GHG reductions that might be achieved by implementing this strategy in Massachusetts or the Boston region.

Feasibility and Timing:

Nationally, the Transportation Research Board considers technical feasibility to be high, institutional feasibility to be low, and political feasibility to vary from high to low.[73]

The timing of this strategy's benefits is short; most benefits could be realized within five years.[74]

MPO Role:

The MPO could study the regional or statewide effects of a policy requiring employers to offer compressed work weeks. This strategy was not included in the list of MPO-fundable strategies because it cannot be implemented by the MPO.

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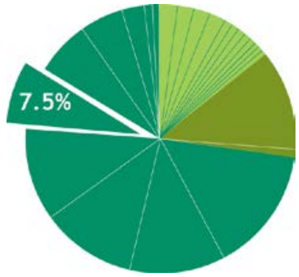
[73] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 26.

[74] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-37.

6) Vehicle-Miles-Traveled Fee



Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	H
Technical Feasibility	L
Institutional Feasibility	H
Political Feasibility	L
MPO Role	Study or Advocate

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities

Description:

Charging drivers according to vehicle miles traveled, or VMT fees, is another pricing-based strategy with high potential to lower GHG emissions. This strategy works similar to pay-as-you-drive insurance in that motor vehicle drivers are encouraged to drive less through pricing distances driven. VMT could be tracked via the same mechanisms possible for implementing PAYD: audited odometer readings and advanced electronics, GPS, and other telematics technologies that can collect VMT data while not tracking location.[75] VMT and PAYD technology could also be used to support congestion pricing.[76]

GHG Reduction:

With a VMT fee of $0.02 to $0.05 per mile, GHG emissions can be reduced by 0.8 to 2.3 percent from the national transportation sector baseline in 2030. [77] A VMT fee of $0.02 to $0.05 is approximately equivalent (in terms of GHG reduction) to a gasoline tax of $0.40 to $1.00.[78] Note that *Moving Cooler* examined the effects of a VMT fee as high as $0.12 per mile for its maximum deployment scenario.

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[75] Cambridge Systematics Inc., *Moving Cooler*, pp. 70-71.

[76] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-25.

[77] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[78] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-18.

Costs and Benefits:

With a direct cost of \$60 to \$150 per $MTCO_2$, a VMT fee has high cost-effectiveness. The high cost-effectiveness and potential for large GHG emission reductions make this a promising strategy.[79]

This strategy may also support capacity management/mobility and clean air/clean communities benefits because it encourages a mode shift away from driving, therefore decreasing VMT and air pollution proportionally (there is also a potential for reduced crashes because of lower VMT).[80] In general, transportation demand-management strategies such as VMT fees "address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[81]

The revenue generated through a VMT fee could be reinvested in transportation finance, which would help make this strategy's effects more equitable. *Moving Cooler* found that this pricing strategy did create inequities for lower income groups, which could be mitigated through transportation programs, e.g., transit and ridesharing programs, to improve mobility. [82]

This pricing strategy would not promote fuel efficiency gains unless the VMT fees also were tied to vehicles' GHG emission rates, fuel efficiency, or weight.[83]

Feasibility and Timing:

A VMT fee strategy faces feasibility challenges. For implementation at the national level, the Transportation Research Board ranks this strategy high in institutional feasibility, but low in technical and political feasibility.[84] In terms of social concerns, this road pricing strategy may be controversial, as it is a new fee and there may be privacy concerns despite technologies that delete locations traveled or offer anonymous accounts.[85] The Massachusetts Legislature has previously considered studying a VMT fee through a pilot study proposed in Bill

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[79] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[80] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 5-19.

[81] USDOT, FHWA, *Reference Sourcebook*, p. 31.

[82] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 4-26–4-27.

[83] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-25.

[84] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[85] USDOT, FHWA, *Reference Sourcebook*, p. 41.

H.2660, *An Act Relative to Transportation Economic Development and Ridership*.[86]

This strategy's timing of benefits is short: Most benefits could be realized within five years.[87]

Data Needs:

No studies have been conducted on the effects of implementing a VMT fee in Massachusetts or the Boston region.

MPO Role:

The MPO does not have the authority to implement VMT fees; however, it could study or advocate for proposals for this strategy.

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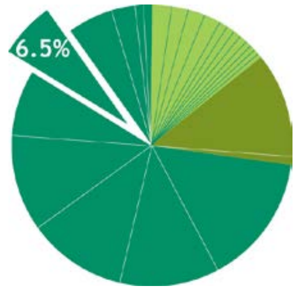
[86] The 189th General Court of Massachusetts, Bill H.2660: An Active Relative to Transportation Economic Development and Ridership, 2015, https://malegislature.gov/Bills/187/House/H2660.

[87] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

7) Reduced Speed Limits to 55 mph



Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	H
Technical Feasibility	H
Institutional Feasibility	M-H
Political Feasibility	L
MPO Role	Study or Advocate

LRTP Goals Addressed:

- Clean Air/Clean Communities
- Safety
- Economic Vitality

Description:

Lowering the speed limit from the current 65 miles per hour (mph) to 55 mph is a promising GHG reduction strategy that requires relatively little expenditure to achieve. Because vehicles rapidly lose fuel economy as they increase speeds greater than 50 mph, setting the speed limit at 55 mph prevents wasted fuel by helping drivers achieve maximum efficiency.[88] The national maximum speed limit had been set at 50 to 55 mph in the past because of energy concerns: The Nixon Administration lowered the speed limit as an emergency response to the 1973 oil crisis. In Massachusetts, the 65 mph speed limit is established in the General Laws, Part I, Title XIV, Chapter 90, Section 17A.[89]

GHG Reduction:

Using the strategy of a lowered national speed limit, Gaffigan and Fleming (2008) calculated GHG reductions of 1.2 to 2.0 percent.[90]

Costs and Benefits:

Establishing a maximum speed limit of 55 mph would be a highly cost-effective means of achieving sizable GHG emissions. The International Energy Agency (2005) estimates a direct cost of only $10 per MTCO$_2$e for this strategy.[91]

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[88] U.S. Department of Energy, www.fueleconomy.gov, Driving More Efficiently, http://www.fueleconomy.gov/feg/driveHabits.jsp (accessed March 17, 2015).

[89] The 189th General Court of the Commonwealth of Massachusetts, *General* Laws, 2015, https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXIV/Chapter90/Section17A

[90] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[91] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

Analyses for state climate action plans have found cost-effectiveness of $-200 (representing a net savings) to $55 per $MTCO_2e$; some of the analyses included vehicle operating cost savings in cost-effectiveness.[92] These cost-savings to drivers support the MPO's economic vitality goal.

Importantly, lower speeds also improve safety by reducing the number of crashes with fatalities and injuries, which addresses the LRTP safety goal.[93] According to a National Academy of Sciences analysis in 1984, an estimated 4,000 traffic fatalities per year were averted as a result of the previous national speed limit (55 mph).[94]

Moving Cooler notes that lower speed limits may increase travel times for multiple groups, and perhaps more for people living in rural areas.[95] Further, a speed-reduction program may have social concerns about increased travel times; however, one study of speed reduction from about 75 mph to 50 mph in Rotterdam, in the Netherlands, found that congestion actually improved downstream from the study area.[96,97] The effects on travel times could be positive or negative.

Setting lower speed limits is also associated with air quality benefits, addressing the MPO's clean air/clean communities goal. The Environmental Protection Agency (EPA) predicts that nitrogen oxide emissions are "about 10 percent lower at 60 mph compared to 65 mph, or 17 percent lower at 55 mph versus 65 mph."[98]

Feasibility and Timing:

The Transportation Research Board names potential implementation challenges, stating that although this strategy "can provide significant benefits at modest cost," it nevertheless is "not likely to be popular, and would require strong

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[92] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 4-39.

[93] Cambridge Systematics Inc., *Moving Cooler*, p. 74.

[94] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 4-39.

[95] Cambridge Systematics Inc., *Moving Cooler*, p. 74.

[96] USDOT, FHWA, *Reference Sourcebook*, pp. 136-137.

[97] European Environmental Agency, Success stories within the road transport sector on reducing greenhouse gas emission and producing ancillary benefits, 2008, Copenhagen, http://www.eea.europa.eu/publications/technical_report_2008_2 (accessed March 13, 2015).

[98] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 4-40.

enforcement to achieve these GHG benefits."[99] National political feasibility is ranked low, technical ranked high, and institutional ranked medium to high.[100]

Most of the benefits from reduced speed limits could be realized within the short-term (five years).[101]

Data Needs:

Studies have not yet been conducted on the effects of implementing a reduced speed limit in Massachusetts or the Boston region. Potential negative or positive effects on travel times in the region are unknown. Additionally, uncertainty exists regarding compliance rates and tolerance by law enforcement of speeding within 10 mph of the speed limit.[102]

MPO Role:

The MPO could advocate for proposals to set reduced speed limits, or it could study the estimated fuel savings and GHG reduction that could be achieved using this strategy.

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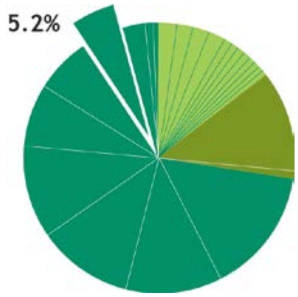
[99] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 34.

[100] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[101] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

[102] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 4-37.

8) Congestion Pricing



Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	M
Technical Feasibility	L
Institutional Feasibility	H
Political Feasibility	L
MPO Role	Study or Advocate

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities

Description:

Congestion pricing is another effective strategy that can be used to reduce greenhouse gas emissions. This concept involves charging a fee for travel during peak periods and/or in certain locations. People may respond by switching from driving to another mode, or by choosing not to drive in certain locations or at certain times to avoid costs associated with congestion pricing.

This strategy may be of particular interest in regional planning: *Cambridge Systematics* states that "of the regional measures evaluated [in *Moving Cooler*], congestion pricing results in the largest impact on reducing GHG emissions." This strategy applies to travel on congested major roads, where more than one-third of highway travel occurs nationally.[103]

London's congestion pricing system provides an example of this strategy in practice. Established in 2003, the London Congestion Zone includes most of Greater London (8.4 square miles) and charges vehicles entering the zone Monday to Friday between 7:00 AM and 6:00 PM about $17 (excluding holidays).[104] A report on London's congestion pricing found that the initiative shifted car occupants to public transportation. Traffic was reduced by about 20 to 30 percent. Bus passengers entering the congestion zone increased 37 percent during the congestion pricing hours in the first year of operation; as much as half of this growth is attributed to former car occupants dissuaded by the congestion charges (the remaining growth reflects the broader bus service improvements). By decreasing traffic volumes and increasing the efficiency of traffic circulation,

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[103] Cambridge Systematics Inc., *Moving Cooler*, p. 40.

[104] Mayor of London, Transport for London, Congestion Charge, http://www.tfl.gov.uk/modes/driving/congestion-charge (accessed March 19, 2015).

congestion pricing directly reduced carbon dioxide emissions from road traffic by 16 percent within the area subject to congestion pricing in the first year.[105] In addition, London has implemented a Low Emission Zone that also covers most of Greater London and uses daily fees to encourage the most polluting heavy diesel vehicles driving in London to become cleaner; it remains in effect 24 hours a day, every day of the year.[106]

In Stockholm, Sweden, a similar congestion pricing zone implemented in 2006 likewise has achieved numerous benefits. A $1.50 to $3 charge has cut traffic volumes by 22 percent, reduced greenhouse gases 14 percent, and increased transit ridership 5 percent. While public opinion was two-thirds against the pricing prior to implementation, understanding of the policy and its benefits has increased; now two-thirds of the public support the strategy. Businesses' sales have increased by 5 percent in the area subject to congestion pricing.[107]

GHG Reduction:

Cambridge Systematics calculated a 1.6 percent possible reduction in GHGs and Energy and Environmental Analysis calculated a 0.5 to 1.1 percent possible reduction through utilization of congestion pricing. Reductions are expressed in a percentage reduction from the national transportation sector baseline in 2030. Cambridge Systematics' high reduction assumes that a roadway level of service (LOS) D is maintained on all roads in the nation, which is equal to an average fee of $0.65 per mile applied to 29 percent of urban and 7 percent of rural roads. Environmental Analysis reductions assume area-wide systems of managed lanes.[108]

Congestion pricing is an example of a strategy that may have a relatively higher impact on GHG emissions in the Boston region than in the nation as a whole, as it is only able to be implemented in certain congested locations. *Moving Cooler* states that, "Of course, in the context of the regions in which congestion pricing is implemented (versus this study's national perspective), the relative impact on GHGs will be greater."[109]

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[105] Transport for London, Central London Congestion Charging, *Impacts monitoring: Fifth Annual Report*, July 2007, http://www.tfl.gov.uk/cdn/static/cms/documents/fifth-annual-impacts-monitoring-report-2007-07-07.pdf (accessed March 19, 2015), pp. 55-57.

[106] Mayor of London, Transport for London, About the LEZ, http://www.tfl.gov.uk/modes/driving/low-emission-zone/about-the-lez (accessed March 19, 2015).

[107] San Francisco County Transportation Authority, *Mobility, Access, and Pricing Study*, 2010, http://www.sfcta.org/sites/default/files/content/Planning/CongestionPricingFeasibilityStudy/PDFs/MAPS_study_final_lo_res.pdf (accessed March 20, 2015).

[108] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[109] Cambridge Systematics Inc., *Moving Cooler*, p. 40.

Costs and Benefits:

A medium direct cost-effectiveness of $340 per metric ton of CO_2e reduced is associated with national implementation of this strategy. No cost estimate is available for the Environmental Analysis calculations.[110]

This strategy potentially supports the Long-Range Transportation Plan goal of capacity management/mobility, depending on implementation, as well as the clean air/clean communities goal. In general, transportation demand-management strategies such as congestion pricing "address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[111]

The main mobility concern with congestion pricing is that lower-income travelers might be priced off the roads without a high-quality alternative mode choice. While drivers who pay the congestion fees could experience a delay reduced by as much as 55 percent (estimated for Puget Sound) and enjoy improved reliability of arrival times, the needs of people for whom the pricing is an outsize burden must be met to support transportation equity.[112] Investing in transit, biking, and walking infrastructure can help address inequities for low-income travelers faced with pricing measures. To illustrate, before London implemented its congestion-pricing program, it first made large investments in the city's bus system.[113]

The Transportation Research Board suggests that congestion pricing, road pricing, and other strategies designed to encourage alternative modes would have a greater GHG reduction effect when implemented where better alternatives exist. Again, better alternatives could be brought about through more compact development or increased investment in transit, bicycling, and walking infrastructure.

Feasibility and Timing:

In order for successful implementation to occur, congestion pricing faces some challenges that need to be tackled. While the Transportation Research Board ranks this strategy high in terms of institutional feasibility, they rank it low in terms of technical and political feasibility for national implementation.[114] In terms of social concerns, public opinion surveys have found 70 percent opposition to

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[110] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[111] USDOT, FHWA, *Reference Sourcebook*, p. 31.

[112] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-27–5-28.

[113] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 31.

[114] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

congestion pricing before implementation, but only 30 percent opposition afterwards; this seems to be because tolls are preferred to taxes when people feel that more funding is needed for transportation.[115] Major cities such as London and Stockholm have successfully implemented this strategy. In the US, San Francisco studied congestion pricing (and found it would have pedestrian safety benefits), but has not yet moved toward implementation.[116]

This strategy's timing of benefits is short, within five years.[117]

Data Needs:

GHG reduction estimates are a very rough approximation; "sophisticated regional models are needed to analyze more sensitively the necessary congestion fees and their impacts, which would vary substantially by facility and by time of day." Such models would need to account for "any increases in off-peak travel if people simply shift the time of their trip rather than forgoing it or choosing an alternative mode."[118]

No studies have been conducted about the effects of implementing congestion pricing in the Boston region or Massachusetts.

MPO Role:

The MPO could advocate for proposals to establish a congestion pricing program. It also could study the GHG reductions that could be reached through various levels of pricing.

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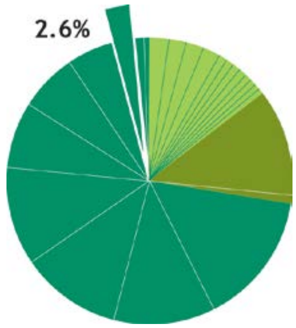
115 USDOT, FHWA, *Congestion Pricing*, A Primer: Overview, 2008, Washington, D.C., http://www.ops.fhwa.dot.gov/publications/fhwahop08039/fhwahop08039.pdf (accessed March 13, 2014).

116 Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

117 Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

118 Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 5-25.

9) Alternative Road Construction Materials



Metrics Summary	Rating
GHG Reduction	M
Direct Cost-Effectiveness	L-H
Technical Feasibility	M-H
Institutional Feasibility	M
Political Feasibility	M-H
MPO Role	Advocate

LRTP Goals Addressed:

- Clean Air/Clean Communities

Description:

State and local highway departments and other transportation agencies can utilize less energy-intensive materials such as (recycled) fly-ash cement and warm-mix asphalt in their highway construction projects to cut their greenhouse gas emissions.[119]

GHG Reduction:

This strategy has the power to reduce national transportation sector GHG emissions by 0.7 to 0.8 percent.[120]

Fly ash substitutes for cement in concrete, currently at a rate of 9.8 percent across the US, with savings of 3.3 $MMTCO_2e$ annually. By increasing the substitution rate to 50 percent, 18.4 $MMTCO_2e$ could be cut each year.[121]

Warm-mix asphalt has the ability to cut GHG emissions from asphalt production by 30 to 40 percent, compared to hot mix asphalt. If it replaced hot-mix asphalt on all roadways, there would be a 2.9 $MMTCO_2e$ national GHG savings.[122]

Costs and Benefits:

Using alternative road construction materials can cost the same as conventional materials in some cases; cost-effectiveness ranges from \$0 to \$770 per $MTCO_2e$ reduced.[123]

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[119] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 4-6.

[120] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[121] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[122] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[123] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

This strategy addresses the MPO's clean air/clean communities goal through lowered air pollution and related environmental benefits as a result of using less energy-intensive technologies. Warm-mix asphalt lowers worker exposure to harmful aerosols and hydrocarbons. It also can reduce plant emissions by "30 to 40 percent for SO_2, 50 percent for VOC, 60 to 70 percent for NOx, and 20 to 25 percent for particulates."[124]

Warm-mix asphalt also provides some benefits for paving, including the ability to pave in cooler temperatures.[125]

Feasibility and Timing:

National adoption of alternative road construction materials has medium intuitional feasibility and medium-to-high technical and political feasibility.[126] Fly ash is a mature technology and practice, so benefits can be achieved in the very near term. However, warm-mix asphalt has not been widely adopted in the US, so benefits would take longer to realize.[127] If the alternative materials are not more costly than the conventional materials, social concerns are not anticipated.[128] In Massachusetts, MassDOT already has chosen warm-mix asphalt as the state standard specification and eliminated hot-mix asphalt.[129]

Once implemented, the timing of benefits for these technologies is short term.[130]

Data Needs:

It is unknown how widely warm-mix asphalt is used at the municipal level in Massachusetts and specifically in the Boston region, and how much further GHGs could be reduced through complete implementation.

MPO Role:

The MPO could advocate for the continued or expanded use of alternative road construction materials at the municipal level. Since the MPO does not directly implement projects, it has limited control over construction decision-making.

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[124] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 4-85.

[125] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 4-85.

[126] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

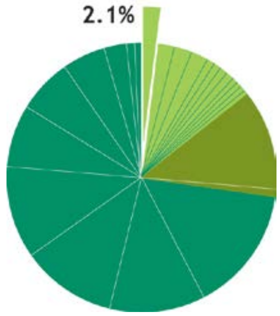
[127] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 4-84–4-85.

[128] USDOT, FHWA, *Reference Sourcebook*, p. 166.

[129] Massachusetts Department of Transportation, *GreenDOT Implementation Plan*, 2012, https://www.massdot.state.ma.us/GreenDOT/GreenDOTReport/GreenDOTImplementationPlan.aspx (accessed December 15, 2015).

[130] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-35.

10) Expansion of Urban Fixed-Guideway Transit



Metrics Summary	Rating
GHG Reduction	M
Direct Cost-Effectiveness	L
Technical Feasibility	M
Institutional Feasibility	H
Political Feasibility	M
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Transportation Equity
- Economic Vitality

Description:

Expansion of urban fixed-guideway transit has the potential to achieve medium GHG reductions, and has the largest potential of the directly MPO-fundable strategies. Many reports suggest that investment in transit could play a significant role in efforts to reduce GHG emissions by shifting travelers to more efficient modes of transportation. *Moving Cooler* makes this point: "Transit investments may be particularly critical if significant pricing strategies are in place, to provide travelers a viable, lower cost alternative to driving."[131]

Expanding urban fixed-guideway transit in the Boston region would mean extending the Massachusetts Bay Transportation Authority's (MBTA) existing rapid transit subway lines or adding new commuter rail or bus rapid transit lines. A project to extend the Green Line through Somerville is currently underway, and additional annual expansion would be needed to meet this strategy's objectives. Large infrastructure projects (urban fixed-guideway transit projects) are capital intensive, but nevertheless this strategy has medium-to-high feasibility and could provide numerous societal benefits.

GHG Reduction:

Expanding urban fixed-guideway transit at a national rate of 2.4 to 4.7 percent annually would garner GHG reductions of 0.17 percent to 0.65 percent by 2030, the highest potential emissions reductions among the transportation

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[131] Cambridge Systematics Inc., *Moving Cooler*, p. 42.

infrastructure strategies that the Boston Region MPO could potentially fund.[132] Importantly, transit also ties in to land-use strategies such as compact development. Transit-oriented development projects nationwide have been found to generate 44 percent fewer weekday vehicle trips, on average, than the amount of trips estimated by the Institute for Transportation Engineers.[133] In addition, GHG reductions from significantly expanded urban transit (together with land use changes and pedestrian and bicycle improvements) would continue to grow through 2050, and could be as much as one-third to twice as large in 2050 compared to 2030. [134] These characteristics make this strategy powerful for meeting the Global Warming Solution Act's statewide 2050 limit.

Costs and Benefits:

GHG reductions from expansion of urban fixed-guideway transit would be achieved at a low cost-effectiveness of $1,800 to $2,000 per MTCO$_2$e.[135] Although transit infrastructure and service improvements have low cost-effectiveness for the implementing agency, these strategies can yield net savings to users as a result of reduced personal vehicle operating costs. Ridership is an important factor in determining the cost-effectiveness and benefits of specific projects, which could be negative if ridership is low.[136] Transit is generally more cost-effective in areas of greater population density like the Boston region, so a region-specific analysis potentially could show improved cost-effectiveness.[137]

Transit has been linked to improved job access, access to educational opportunities (supporting increased employment), and access to preventative health care. Following the startup of new transit services, increased job opportunities have been found for low-wage workers, demonstrating the critical role transit can play in employment. Improved access to preventative health care can help individuals avoid the need for emergency care visits, resulting in cost savings.[138]

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[132] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[133] Transportation Research Board, Transit Cooperative Research Program, *Effects of TOD on Housing, Parking, and Travel*, 2008, Washington, D.C., http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_128.pdf (accessed March 20, 2015).

[134] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. ES-6.

[135] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[136] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 33-34.

[137] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 33.

[138] National Cooperative Highway Research Program, Selected Indirect Benefits of State Investment in Public Transportation, Research Results Digest 393, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_393.pdf.

Public transportation can provide transportation equity benefits in the Boston region by alleviating part of any mobility loss as a result of pricing measures, potentially helping to meet the LRTP transportation equity goal. Strategies that improve public transportation can provide a higher proportion of benefits to lower-income groups, as these groups rely on public transportation more than other groups. Similarly, this strategy would provide a higher proportion of benefits to other groups without other transportation mode choices, such as those who reside in rural areas and individuals without access to automobiles.[139] However, rising property values and rent increases associated with transit improvements potentially could result in displacement of lower-income residents; housing measures may be needed to ensure the most equitable outcomes.[140]

The strategic combination of significantly expanding urban transit while making land use changes and pedestrian and bicycle improvements also can "increase mobility, lower household transportation costs, strengthen local economies, and provide health benefits by increasing physical activity."[141] This strategy's importance to compact development means that implementation should explicitly consider the impact on land use to ensure favorable outcomes. If transit expansion is implemented in a way that fosters low-density suburban development, the goals of a compact development strategy may not be met, with adverse effects on other strategies that depend upon it. [142]

This strategy may also support the MPO's capacity management/mobility and clean air/clean communities goals since it increases the percentage of population and places of employment within one-quarter mile of transit stations and stops and encourages a mode shift away from driving, decreasing VMT and associated pollution. In general, transportation demand-management strategies such as new transit infrastructure "address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[143]

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[139] Cambridge Systematics Inc., *Moving Cooler*, p. 74.

[140] Dukakis Center for Urban and Regional Policy, Northeastern University, Maintaining Diversity in America's Transit-Rich Neighborhoods: Tools for Equitable Neighborhood Change, http://www.northeastern.edu/dukakiscenter/transportation/transit-oriented-development/maintaining-diversity-in-americas-transit-rich-neighborhoods/ (accessed March 25, 2014).

[141] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. ES-6.

[142] USDOT, FHWA, *Reference Sourcebook*, p. 95.

[143] USDOT, FHWA, *Reference Sourcebook*, p. 31.

Feasibility and Timing:

The Transportation Research Board gives this strategy medium technical and political feasibility and high institutional feasibility.[144] Expanding transit service can be popular or controversial, depending on the location, cost, proposed fares, and proposed land uses.[145]

This strategy has medium timing of benefits; most benefits could be realized within five to twenty years.[146]

Data Needs:

Significant expansions to the MBTA's transit system at the scale proposed in this GHG reduction strategy have not been studied. MassDOT and the MBTA are currently developing their Program for Mass Transportation – Focus40, which will analyze and recommend transit improvements for future consideration.

Furthermore, non-fixed guideway transit (e.g., buses) was not studied in this literature review. The GHG reduction potential and cost-effectiveness of this alternative type of transit is unknown, but also is potentially promising. Federal Transit Administration data on average CO_2 emissions per passenger mile by mode show that the emission rate from private automobiles is higher than that from bus transit (although the bus transit rate is higher than the various rail rates). Bus transit emission rates also are projected to decrease by 50 percent by 2050 because of technological improvements.[147]

MPO Role:

If there is an opportunity to help fund a new or extended transit line, the MPO could flex highway funds to support construction of the project. The MPO previously contributed funds to construct the new Assembly Square Orange Line station and the MBTA's Green Line Extension to Medford. The MPO also could continue to study the feasibility, benefits, and challenges associated with implementing various types of transit infrastructure or service.

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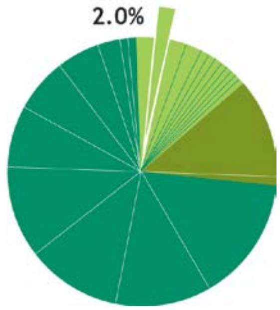
[144] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[145] USDOT, FHWA, *Reference Sourcebook*, pp. 94-95.

[146] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

[147] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 5-35–5-38.

11) Teleworking



Metrics Summary	Rating
GHG Reduction	M
Direct Cost-Effectiveness	L
Technical Feasibility	M
Institutional Feasibility	L
Political Feasibility	M-H
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities

Description:

Teleworking, or telecommuting, occurs when employees conduct their workday at home or otherwise outside their employer's office, using telecommunications and computer technology to overcome the distance. Most teleworkers across the country work from home, although a very small subset works from telecenters, or small offices that are closer to employees' homes than the main office. Public-sector programs can play a role in encouraging employers to adopt teleworking policies. Surveys indicate that between half and three-quarters of workers offered the option of telecommuting would be interested.[148]

Employers can support teleworking through both formal and informal policies. Potential technological investments also may be needed to support teleworking, although some employees may not need additional technological infrastructure in order to work from home.

GHG Reduction:

Teleworking as a GHG reduction strategy has the potential to cut national greenhouse gas emissions by 0.5 to 0.6 percent if current levels of teleworking are doubled.[149] Teleworking reduces GHG emissions because VMT decreases substantially as commute trips decrease. Although there can be a "rebound effect" where some of the decreased commute VMT is cancelled out by trips that the worker would have made on the way home from work and still needs to complete, it is estimated that this accounts for only one-quarter of daily VMT. This strategy's GHG-reduction estimates account for this rebound effect,

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[148] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-77–5-81.

[149] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

although they do not account for increased home energy use (perhaps 11 to 25 percent of travel energy savings) or the fact that individuals may choose to live further from their workplace when teleworking is an option, thereby increasing VMT on days when they do not telecommute.[150]

Costs and Benefits:

This strategy, at $1,200 to $2,300 per $MTCO_2e$ reduced, has low cost-effectiveness.[151] However, some research suggests that costs likely would decline in the future.[152]

Benefits of teleworking identified by EPA and Congress include “enhanced worker productivity and morale, improved employee attraction and retention, and reduced overhead expenses.” Telework can also enhance mobility and productivity of travel. [153]

This strategy may also support the Long-Range Transportation Plan goals of capacity management/mobility and clean air/clean communities, as it encourages decreased VMT; and can be considered to enhance mobility, as it allows workers to perform activities while eliminating the time and costs of travel.[154] In general, transportation demand-management strategies such as teleworking “address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions.”[155]

Feasibility and Timing:

This strategy generally is supported by private-sector trends. More and more US workers are choosing to work from home as the technology used in teleworking has improved and fuel prices have increased. Between 2001 and 2008 the number of workers employed by a company and teleworking has increased from approximately 8 million to 17 million. When self-employed and contract workers are included, the total number of workers teleworking was 17 million in 2001 and 34 million in 2008. Nearly three-quarters of employee teleworkers (24.2 million

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[150] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, pp. 5-77–5-81.

[151] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[152] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, pp. 5-77–5-81.

[153] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, pp. 5-77– 5-81.

[154] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, Volume 2, pp. 5-80.

[155] USDOT, FHWA, *Reference Sourcebook*, p. 31.

people) work from home at least once per week, representing 18 percent of the employed American workforce.[156]

The Transportation Research Board gives telework a range of feasibility rankings: medium technical, low institutional, and medium-to-high political.[157] There are few social concerns from the public or individual employees about teleworking. More often, employers may resist telework programs because of concerns about managing employees remotely, despite the identified benefits.[158] Increasing teleworking and meetings by web conference is a MassDOT GreenDOT goal.[159]

Most of the benefits of teleworking could be achieved within five years of implementation.[160]

Data Needs:

Information is not available about the percentage of the Boston region or Massachusetts workforce that could take advantage of teleworking. The GHG reduction potential of this strategy has not been studied on a regional or statewide scale.

MPO Role:

Although expansion of teleworking has been driven largely by the private sector, some public-sector programs have been influential as well. A study of teleworking in Washington, D.C. calculated that the Maryland and Virginia Telework Program was responsible for about 10 percent of the District's 0.5 $MMTCO_2$ GHG reductions. In order to encourage and support private businesses in adopting telework, government agencies can institute outreach programs, technical assistance, or incentives such as tax credits or recognition.[161]

MassRIDES advertises that it provides telework and flextime policy guidance to partner employers.[162] The MPO, in conjunction with MassRIDES, could support a telework outreach program through the Clean Air and Mobility Program using CMAQ funds. Teleworking could be included as a strategy in a Workplace

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[156] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-77 – 5-81.

[157] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.

[158] USDOT, FHWA, *Reference Sourcebook*, p. 100.

[159] Massachusetts Department of Transportation, *GreenDOT Implementation Plan*, 2012, https://www.massdot.state.ma.us/GreenDOT/GreenDOTReport/GreenDOTImplementationPlan.aspx (accessed December 15, 2015).

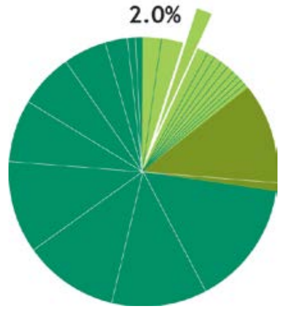
[160] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 3-36.

[161] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-77 – 5-81.

[162] Massachusetts Department of Transportation, MassRIDES, Partnership Program, 2015, http://www.commute.com/employer-options/partnership-program (accessed December 15,2015).

Transportation Demand Management package offered by employers (see Strategy 13 below for more information). Information about teleworking could be disseminated through the MPO's public information channels. The MPO also could study the impact of teleworking on transportation in Massachusetts.

12) Increased Transit Service



Metrics Summary	Rating
GHG Reduction	M
Direct Cost-Effectiveness	L
Technical Feasibility	H
Institutional Feasibility	H
Political Feasibility	H
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Transportation Equity
- Economic Vitality

Description:

Improving transit headways and level of service has the third-greatest potential to reduce greenhouse gas emissions of MPO-fundable strategies (that are not "publicize only"). As the quality and convenience of transit services increase, people are more inclined to switch from automobile trips to transit trips, reducing VMT and GHG emissions. Many reports suggest that investment in transit could play a significant role in efforts to reduce GHG emissions by shifting travelers to more efficient modes of transportation. *Moving Cooler* notes "Transit investments may be particularly critical if significant pricing strategies are in place, to provide travelers a viable, lower cost alternative to driving."[163] While this strategy is unfortunately one of the most costly means of GHG reductions, it has many other benefits in addition to GHG reductions and is considered one of the most feasible strategies.

GHG Reduction:

Nationally, if transit service is increased 1) by a minimum of 40 percent for off-peak service, and 2) as much as a maximum of 10 percent more for peak service, the International Energy Agency calculates that GHG emissions reductions of 0.2 to 0.6 percent could be realized.[164]

A study of transit agencies that saw rising ridership in the second half of the 1990s found that increased service levels caused growth in ridership. Transit

[163] Cambridge Systematics Inc., *Moving Cooler*, p. 42.

[164] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.

agencies that increased their service hours (revenue vehicle hours) the least had the highest rates of return; an average of a 4.3 percent increase in service hours garnered an 8.5 percent rise in ridership. Despite declining rates of return, the agencies that increased their service hours the most saw the largest total ridership gains. On average, a 79 percent increase in service hours resulted in a 64.1 percent increase in ridership. However, the level of transit service provided is a function of demand, so there is no guarantee that increasing service will result in a corresponding ridership growth.[165].

Costs and Benefits:

The cost estimate of increasing transit service by a minimum of 40 percent more off-peak service and as much as a maximum of 10 percent more peak service would be \$3,000 to \$3,300 per $MTCO_2e$.[166] Although transit infrastructure and service improvements have low cost-effectiveness for the implementing agency, these strategies can yield net savings to users as a result of reduced personal vehicle operating costs.[167] In addition, while this range is at the low end of GHG reduction cost-effectiveness, it also includes many other benefits such as increased equity and economic vitality.

Transit has been linked to improved job access, access to educational opportunities (in this way supporting increased employment), and access to preventative health care. Following the startup of new transit services, increased job opportunities have been found for low-wage workers, demonstrating the critical role transit can play in employment. Improved access to preventative health care can help individuals avoid the need for emergency care visits, resulting in cost savings.[168]

Public transportation can provide transportation equity benefits in the Boston region by alleviating part of any mobility loss as a result of pricing measures, potentially helping to meet this LTRP goal. Strategies that improve public transportation can provide a higher proportion of benefits to lower-income populations since they rely on public transportation more than other populations. Similarly, this strategy will provide a higher proportion of benefits to populations without other transportation mode choices, such as those who reside in rural areas and individuals without access to automobiles.[169] However, rising property values and rent increases associated with transit improvements potentially could

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[165] USDOT, FHWA, *Reference Sourcebook*, pp. 91-92.

[166] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[167] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 33-34.

[168] National Cooperative Highway Research Program, Selected Indirect Benefits of State Investment in Public Transportation.

[169] Cambridge Systematics Inc., *Moving Cooler*, p. 74.

result in displacement of lower-income residents; housing measures may be needed to ensure the most equitable outcomes.[170]

This strategy may also support the MPO's goals of capacity management/mobility and clean air/clean communities' benefits since it encourages a shift away from driving, decreasing VMT, and also may improve the reliability of transit. In general, transportation demand-management strategies such as increasing transit service "address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[171]

Feasibility and Timing:

This strategy is considered to have high technical, institutional, and political feasibility at the national level, which makes it almost unique among the list of potential strategies for reducing GHG emissions.[172] Adding new transit service can be popular or controversial, depending on costs and other factors.[173]

Increased transit service has medium timing of benefits; most benefits could be realized within five to twenty years.[174]

Data Needs:

The MPO has conducted a number of studies for increased transit service in the Boston region, including late night transit service, South Station Expansion, and increased service as part of Green Line extension mitigation. However, these studies do not entirely capture the complete picture of full implementation of this strategy.

MPO Role:

The MPO could fund increased transit service to improve transit headways and level of service strategically, potentially through the Clean Air and Mobility program. The MPO can continue to study methods of improving transit service, and the potential impacts of these improvements, at various locations in the MPO region.

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[170] Dukakis Center for Urban and Regional Policy, Maintaining Diversity in America's Transit-Rich Neighborhoods: Tools for Equitable Neighborhood Change.

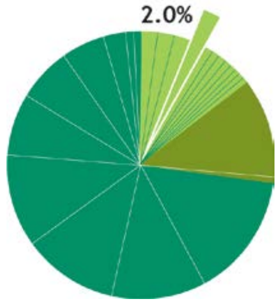
[171] USDOT, FHWA, *Reference Sourcebook*, p. 31.

[172] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.

[173] USDOT, FHWA, *Reference Sourcebook*, pp. 94-95.

[174] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

13) Workplace Transportation Demand Management (General)



Metrics Summary	Rating
GHG Reduction	M
Direct Cost-Effectiveness	H
Technical Feasibility	H
Institutional Feasibility	L-H
Political Feasibility	H
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Economic Vitality

Description:

Transportation-demand management refers to strategies that improve capacity management and mobility by encouraging a shift from single-occupant vehicle (SOV) trips to non-SOV modes (such as to car pools).[175] The goal of workplace transportation demand management (TDM) is to reduce commuter trips by SOVs, and can take the form of requirements for employers to reduce SOV trips or outreach programs to encourage them to do so. During the 1970s energy crisis, transportation agencies were encouraged to develop workplace TDM programs; these programs continue to exist. Metropolitan planning agencies and State Departments of Transportation could implement this strategy and provide voluntary/outreach-based worksite trip-reduction programs.[176]

GHG Reduction:

Widespread employer outreach and alternative mode support can cut greenhouse gas emissions by 0.1 to 0.6 percent. Of the various tools for encouraging workplace TDM, financial incentives and disincentives such as discounted transit passes and parking pricing or cash-out have been found to have a greater effect than simply providing information or through coordination. Parking pricing or parking cash-out involves charging workers for parking or allowing them to "cash out" the value of unused parking. Employees' willingness to shift modes is also affected by other factors, such as the quality of alternatives

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175 http://www.seattle.gov/transportation/docs/ump/07%20SEATTLE%20Best%20Practices%20in%20Transportation%20Demand%20Management.pdf.

176 Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-74–5-77.

to SOV driving and fuel pricing, which can be influenced through complementary strategies.[177]

As a local example, the City of Cambridge established requirements for some employers to reduce SOV trips. The City's Parking and Transportation Demand Management (PTDM) ordinance, originally adopted in 1998, serves as a national model for SOV reduction. The ordinance applies to non-residential properties where an owner proposes to increase parking, and requires owners of 20 or more parking spaces to submit a PTDM plan to ensure that the mode share of SOV drivers is less than 10 percent of 1990 levels. The ordinance gives the city the ability to fine and even close parking at workplaces that fail to meet the ordinance's standards; however, the city has never needed to put these tools into action to achieve compliance. The success of the PTDM ordinance is captured in Kendall Square, which in the past decade saw a 40 percent increase in commercial and institutional space, while automobile traffic decreased on major streets by as much as 14 percent. Less than half of the workers at some workplaces travel in SOVs.[178]

Costs and Benefits:

This strategy is highly cost-effective, at \$30 to \$180 per $MTCO_2e$.[179] The costs of demand-management strategies include administrative program coordination costs, which would be paid by local and regional agencies and employers. Large state and regional TDM programs usually employ five to ten full-time staff equivalents. Many TDM programs also involve transfer payments, such as transit fare subsidies provided by an employer or regional agency, or new revenue gathered through parking fees. This strategy has resulted in large vehicle cost savings for employees, addressing the MPO's economic vitality goal.[180]

According to MassRIDES, benefits to employers who implement workplace transportation demand-management strategies include improved employee productivity, easier recruitment and retention, reduced absenteeism and late arrivals, increased employee morale, reduced parking and office space needs

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[177] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-74 – 5-77.

[178] City of Cambridge, Community Development Department, Parking and Transportation Demand Management Ordinance, http://www.cambridgema.gov/CDD/Transportation/fordevelopers/ptdm.aspx (accessed March 13, 2015).

[179] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.

[180] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-74 – 5-77.

and costs, easier access and traffic flow at the work place, tax savings, and enhanced corporate image.[181]

General workplace TDM may support the MPO's goals of capacity management/mobility and clean air/clean communities, as it encourages a mode shift away from single-occupancy vehicles, in turn decreasing VMT. Most workplace TDM programs "will result in additional mobility options for commuters."[182]

Feasibility and Timing:

In Massachusetts, MassDOT has established MassRIDES, a free program that works with employers and commuters to encourage them to help reduce traffic congestion and improve air quality and mobility. MassRIDES uses "hands-on worksite assistance, ride-matching services, marketing and outreach events" to reduce VMT by 23 million miles and air pollution by 10,000 tons annually.[183] The Boston region also contains eleven local transportation management associations (TMAs): A Better City TMA, Allston Brighton TMA, Charles River TMA, CommuteWorks/MASCO, Seaport TMA, TranSComm, 128 Business Council, The Junction TMO, MetroWest/495 TMA, Neponset Valley TMA, and North Shore TMA.[184]

Massachusetts has a rideshare regulation that requires businesses and educational institutions with 1,000 or more commuters and businesses with 250 or more commuters that are subject to the Massachusetts Air Operating Permit Program to develop plans and set goals for reducing commuter drive-alone trips by 25 percent.

The Transportation Research Board gives workplace transportation demand-management a high rating for technical and political feasibility, and a low-to-high rating for institutional feasibility.[185] Voluntary TDM measures such as ride sharing

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[181] MassRIDES, Partnership Program, Massachusetts Department of Transportation, http://www.commute.com/employer-options/partnership-program (accessed December 3, 2015).

[182] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 5-74.

[183] Massachusetts Department of Transportation, MassRIDES, "About MassRIDES," http://www.commute.com/about-massrides (accessed March 9, 2015).

[184] MassCommute, List of MA TMAs, http://www.masscommute.com/tma_directory/ (accessed March 25, 2015).

[185] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

are widely accepted, while mandatory TDM ordinances can be controversial.[186] Expanding TDM programs by 20 percent is a MassDOT GreenDOT goal.[187]

Most of this strategy's benefits could be realized in the short term, within five years.[188]

Data Needs:

MassRIDES and the eleven local transportation management associations in the Boston region already provide TDM services. The potential for additional GHG reductions through this strategy is unknown, and implementation of additional measures has not been studied.

MPO Role:

MassRIDES has been established for general workplace transportation demand-management in Massachusetts, and eleven TMAs serve various communities in the Boston region. The Massachusetts Department of Environmental Services administers the Commonwealth's rideshare regulation. The MPO could study the impacts of workplace TDM programs on travel and GHG emissions to see what types of services are most effective in changing travel behavior. It could also continue to provide technical support to the region's TMAs.

In order to see further cuts in GHG emissions, the MPO could consider contributing funding to MassRIDES or the TMAs through the Clean Air and Mobility program in order to expand their impact. In addition, the MPO could provide startup funding for TMA programs and provide information about the benefits of this strategy through its public outreach venues. Voluntary workplace TDM programs should involve financial incentives and disincentives for employees in order to reach maximum effectiveness.

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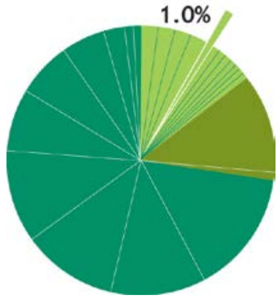
[186] USDOT, FHWA, *Reference Sourcebook*, p. 75.

[187] Massachusetts Department of Transportation, *GreenDOT Implementation Plan*, 2012, https://www.massdot.state.ma.us/GreenDOT/GreenDOTReport/GreenDOTImplementationPlan.aspx (accessed December 15, 2015).

[188] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

14) Pedestrian Improvements



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	H
Technical Feasibility	H
Institutional Feasibility	L-M
Political Feasibility	M
MPO Role	Fund or Study

LRTP Goals Addressed:

- Safety
- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Transportation Equity
- Economic Vitality

Description:

Improved walking infrastructure can encourage people to choose walking instead of driving, thus reducing VMT and GHG emissions. This strategy assumes that pedestrian improvements are implemented near business districts, schools, and transit stations. Pedestrian improvements include adding or improving sidewalks, crosswalks, crossing signals, and shared-use paths, among others.

GHG Reduction:

If this strategy is implemented, a GHG reduction of 0.10 to 0.31 percent is possible.[189] Again, pedestrian improvements would have the greatest effect if compact, mixed-use development strategies are implemented simultaneously. Notwithstanding, where destinations already are relatively close together and pedestrian trips are discouraged by lack of sidewalks or safe crossings, this strategy can reduce VMT and GHG. To illustrate this at the national level, of the nearly 25 percent of all trips that are less than one mile, about three-quarters of them are made by automobile. Furthermore, less than one-third (fewer than 30 percent) of nationwide trips to school by children ages 5 to 15 are made by walking or bicycling.[190] There is great potential to shift automobile trips to walking trips.

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[189] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[190] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

Because the Boston region has greater population densities than much of the country, more trips may be suitable for walking than for national trips as a whole. This strategy could help achieve a larger share of regional emissions reductions than the national percentages suggest; see similar discussion regarding bicycle improvements.

Costs and Benefits:

Pedestrian improvements are highly cost-effective, as they can be implemented at $190 per MTCO$_2$e.[191] Some pedestrian improvements, such as incorporating enhanced pedestrian crossings into new or reconstructed roadways are low-cost, while more costly improvements include retrofitting suburban areas with sidewalks.[192]

The Long-Range Transportation Plan goal of capacity management/mobility may also be supported by this strategy as it creates a connected network of accessible sidewalk facilities by expanding existing facilities and closing gaps. It also encourages a mode shift away from driving, decreasing VMT.

Improvements to pedestrian (and bicycle) accommodations come with key public health and transportation equity benefits. *Moving Cooler* states that investment in pedestrian and bicycle modes "can have substantial positive equity effects by increasing mobility for lower income groups and all those without significant access to vehicles." Those without significant access to vehicles include youth, the elderly, disabled persons, lower income individuals, or other individuals without driver permits. Having walking and biking as newly available transportation options would enhance the ability of individuals in these groups to access needed services.[193]

The LRTP's economic vitality goal may be well supported by pedestrian and bicycle strategies. These modes offer substantial vehicle cost savings; when the costs of implementation are considered together with vehicle cost savings for users, there are net savings of $600 to $700 per MTCO$_2$.[194]

The safety benefits of pedestrian facilities are significant. Roadways with sidewalks on both sides of the street have half the likelihood of pedestrian crashes as sites without sidewalks. The presence of sidewalks "dramatically

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191 Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

192 Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-6.

193 Cambridge Systematics Inc., *Moving Cooler*, p. 74.

194 Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

increases" how well people perceive that their needs are being met as they walk along a roadway.[195]

Pedestrian and bicycle facility improvement strategies also generate benefits in terms of increased physical activity and improved public health. Around 70 percent of American adults do not achieve recommended levels of physical activity, and sedentary lifestyles are associated with the rapid increase in the percentage of Americans that are overweight and obese. Environments that are unsafe for walking and biking influence decisions not to choose these transportation options. However, if these modes can be made safer, allowing more people to walk and bike, a great health benefit could be realized.[196, 197]

Pedestrian and bicycle improvements, like transit, benefit from the presence of compact development. These non-motorized modes support transit use by making connections to and from transit stops, and, like transit, are "much more effective" where destinations are close together in densely developed areas.[198]

Feasibility and Timing:

In *Growing Cooler: The Evidence on Urban Development and Climate Change*, adopting a statewide Complete Streets policy and funding program is named as a state policy recommendation for reducing greenhouse gases. Complete Streets policies could be used to implement the widespread pedestrian improvements needed for this strategy to succeed. *Growing Cooler* names three components of complete streets policies:

- A requirement that pedestrian and bicycle facilities be provided on all new and reconstructed streets and highways, and that pedestrians' and bicyclists' needs be considered in routine roadway operation and maintenance
- A mandate that new streets be interconnected and cul-de-sacs be discouraged so that travel distances for pedestrians and bicyclists are minimized
- Adequate state-level funding commensurate with actual and desired levels of biking and walking. If biking and walking trips make up ten percent of the mode split, then dedicating only one percent of state highway funds to

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[195] U.S. Department of Transportation, *Safety Benefits of Walkways, Sidewalks, and Paved Shoulders*, 2013, Federal Highway Administration, http://safety.fhwa.dot.gov/ped_bike/tools_solve/walkways_trifold/.

[196] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

[197] Centers for Disease Control and Prevention, "Obesity and Overweight," http://www.cdc.gov/nchs/fastats/obesity-overweight.htm (accessed March 6, 2015).

[198] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-6.

> these trips would be insufficient. If the goal is to double or triple these types of trips, funding levels will "have to be commensurate" in order to "stand a chance of meeting this objective."[199]

Massachusetts incorporated Complete Streets principles into the 2006 MassDOT Highway Division Project Development and Design Guide, helping to ensure that pedestrian facilities are included in transportation projects. Featuring and prioritizing pedestrian facilities in designs rather than simply accommodating them is a MassDOT GreenDOT goal.[200] Furthermore, the Massachusetts Legislature recently implemented a Chapter 90-I Complete Streets Program that will provide $200 million in funding (12 percent of fiscal year 2016 capital investment) to communities in order to further "Complete Streets" goals such as increasing the safety and comfort of people walking and biking.[201, 202] This program could provide an important step towards achieving the comprehensive pedestrian improvements needed to meet the objectives of this strategy.

The Transportation Research Board ranks the pedestrian improvements GHG reduction strategy high for technical feasibility, low-to-medium for institutional feasibility, and medium for political feasibility.[203]

Most benefits could be realized within five to twenty years.[204]

Data Needs:

The potential for additional GHG reductions through this strategy in the Boston region and Massachusetts is unknown, and implementation of additional measures is not available at this time. However, the MPO recently adopted a work program to develop a method for calculating pedestrian levels of service in the region and provide guidance for its implementation. The program will help

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[199] Urban Land Institute, *Growing Cooler: The Evidence on Urban Development and Climate Change*, 2008, by Reid Ewing, et. al., Washington, D.C.

[200] Massachusetts Department of Transportation, *GreenDOT Implementation Plan*, 2012, https://www.massdot.state.ma.us/GreenDOT/GreenDOTReport/GreenDOTImplementationPlan.aspx (accessed December 15, 2015).

[201] Massachusetts Department of Transportation, MassDOT Capital Investment Plan Fiscal Year 2016, 2015, https://www.massdot.state.ma.us/Portals/0/docs/infoCenter/docs_materials/FY16_FinalCapitalBudget.pdf (accessed December 2, 2015).

[202] The 189th General Court of Massachusetts, General Laws, Chapter 90I Complete Streets Program, 2015, https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXIV/Chapter90I/Section1 (accessed December 2, 2015).

[203] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

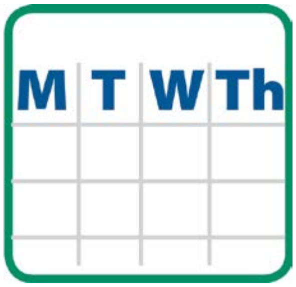
[204] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

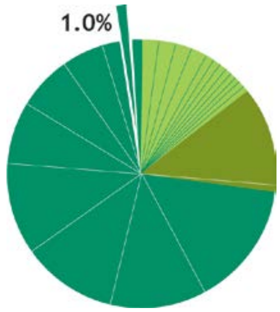
identify areas for improvement to pedestrian facilities in the region. It also will inventory data that is readily available for analyzing pedestrian facilities.

MPO Role:

Through its livability program and other bicycle and pedestrian planning activities, the MPO conducts ongoing pedestrian and bicycle planning activities such as studies and technical assistance. It then funds implementation of some of the small-scale roadway, intersection, bicycle, and pedestrian facilities that are recommended in these and other MPO evaluations and studies. The Congestion Mitigation and Air Quality Improvement program provides funding for implementing these small-scale projects and for constructing larger facilities such as a multi-use path in Somerville. In the MPO's recently adopted LRTP, *Charting Progress to 2040*, six percent of the LRTP's overall funding over the 25-year life of the plan was allocated to a bicycle and pedestrian program to fund these types of improvements. To match the aggressive levels of targeted improvements near business districts, schools, and transit stations called for in the GHG strategy, the MPO could increase funding dedicated to implementing pedestrian improvements.

15) Compressed Workweek: Mandatory Public and Voluntary Private





Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	NA
Technical Feasibility	H
Institutional Feasibility	L
Political Feasibility	L-H
MPO Role	Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Economic Vitality

Description:

A compressed work schedule allows an employee to work a traditional 35-40 hour workweek in less than the traditional number of work days, which would reduce the number of days that employees would need to commute.[205] While a requirement for both public and private sector employers to offer a compressed work week would garner high GHG reductions, as discussed previously, this different compressed work week strategy is another viable option that would have a moderate effect on emissions. This strategy proposes implementing compressed work weeks for the public (government) sector and expanding voluntary private adoption of the strategy.

GHG Reduction:

If a minimum of 75 percent of government employees nationwide were required to work a four-day-40-hour work week, GHG emissions would be reduced at least 0.1 percent. If current private participation were doubled, in addition to the public sector efforts, the maximum 0.3 percent emissions reductions could be reached.

The public sector represents 14 percent of US employment. It may be easier to implement required compressed work weeks in the public sector than to double voluntary compressed work weeks in the private sector, although the private sector holds the potential for the largest GHG reductions.[206]

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[205] https://www.hr.cornell.edu/life/support/compressed_work_week.html

[206] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-81–5-84.

In order to understand a doubling of private sector participation, Cambridge Systematics and Eastern Research Group examined a number of studies of compressed work week participation. Current estimates put the number of private employers offering compressed work weeks at 33 to 44 percent nationwide. Assuming that employees in newly offering workplaces would elect to adopt compressed work weeks at the same rate, then 66 to 88 percent of private employees would need to offer this option in order to achieve twice the private sector participation. Doing so would reduce 14 billion VMT each year nationwide.[207]

Costs and Benefits:

No direct cost-effectiveness information is available.[208]

For three years beginning in 2008, Utah's state employees adopted a mandatory four-day work week, demonstrating implementation of this GHG reduction strategy. The compressed work week was estimated to cut 12,000 $MTCO_2$ and collectively save employees \$5 million to \$6 million annually through reduced commuting costs. The program was popular overall with both the employees and the public. A 2009 survey of state employees found that 82 percent wanted to continue the program. Twice as many state residents thought the program was a good idea (60 percent) as thought it was a bad idea (28 percent).[209] A program like this would address the LRTP's economic vitality goal. A few U.S. cities have also adopted four-day work weeks: Gainesville, FL, Huntington, WV, and El Paso, TX.[210]

Although compressed work weeks may be popular on the whole, "not all employees would prefer longer work days or have compatible personal schedules. Therefore, if compressed work weeks are made mandatory, it will benefit some employees and be a disadvantage to others."[211] The first compressed work-week strategy, required employer-offered compressed work week, would allow employees to choose their schedules, thereby addressing this potential negative effect.

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[207] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-81–5-84.

[208] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[209] Brook Vergakis, Associated Press, Utah gov keeps 4-day workweek, *Casper Star Tribune*,December 3, 2009, http://trib.com/news/state-and-regional/article_78cef17e-2897-5595-9e32-4c5e174e79da.html (accessed March 19, 2014).

[210] Jessica Mulholland, Is a Four-Day Workweek Desirable?, *Governing*, August 2011, http://www.governing.com/topics/public-workforce/Is-a-Four-Day-Workweek-Desirable.html (accessed March 19, 2014).

[211] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 5-83.

Benefits to capacity management/mobility also may be supported by compressed work weeks as they decrease VMT. This strategy can relieve peak-period congestion because “participating employees work longer hours than a traditional 9 to 5 schedule.”[212]

Feasibility and Timing:

Nationwide technical feasibility is ranked high, institutional feasibility is ranked low, and political feasibility may vary from high to low.[213] The timing of benefits for compressed work weeks is short-term; most benefits can be attained within five years.[214]

Data Needs:

The GHG reduction potential of this strategy has not been studied at the regional or statewide scale.

MPO Role:

The MPO could study the impacts of governmental compressed work weeks along with its anticipated GHG reduction in the region. The MPO could conduct a study in conjunction with MassRIDES about the feasibility of increasing voluntary private-sector participation, including the benefits of offering compressed work weeks and its potential as part of a larger work-place TDM outreach program.

This strategy was not included in the list of MPO-fundable strategies, as the minimum assumption, a requirement for government employees, cannot be implemented by the MPO. Nevertheless, the MPO could fund outreach about compressed work weeks to help contribute to increased private-sector participation.

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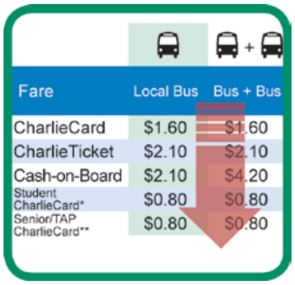
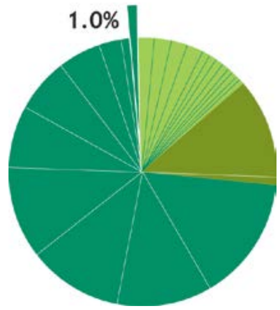
[212] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, Volume 2, pp 5-83.

[213] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[214] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, pp. 3-37.

16) Transit Fare Reduction





Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	L
Technical Feasibility	H
Institutional Feasibility	H
Political Feasibility	H
MPO Role	Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Economic Vitality

Description:

The potential to save greenhouse gas emissions through a large fare reduction of 50 percent could be promising, but there appears to be uncertainty in the magnitude of potential reductions. This strategy could be studied by the Boston Region MPO.

GHG Reduction:

According to the International Energy Agency (IEA), a 50-percent fare reduction would save 0.3 percent of transportation-sector GHG emissions. However, Cambridge Systematics estimates that fare reductions as much as 50 percent can achieve only as much as 0.09 percent GHG emissions reductions.[215] Based mainly on studies in North America, IEA assumes a price elasticity of -0.3, which means that ridership increases three percent when price is reduced 10 percent; this varies according to peak and off-peak travel, as well as between bus and rail travel.[216] Cambridge Systematics' analysis assumes average vehicle occupancy of 1.43 and VMT per trip of 5.12 miles, also with -0.3 price elasticity.[217] It is unclear why the two analyses differ in their conclusions regarding GHG emissions reduced. FHWA separately notes that the effects of transit benefits on ridership can vary and external factors may be significant.[218]

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[215] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[216] International Energy Agency, *Saving Oil in a Hurry*, OECD, Paris, France, pp. 55.

[217] Cambridge Systematics, Inc., Technical Appendices, *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*, 2009, p. C-24.

[218] USDOT, FHWA, *Reference Sourcebook*, pp.83-85.

Transit fare reduction cannot be implemented in areas without transit, and because Massachusetts and the Boston region have more transit service than the nation on average, this strategy may have an effect greater than the average 0.09 or 0.3 percent reduction where implemented.

Costs and Benefits:

IEA projects that this strategy would cost more than some others, at $1,300 per $MTCO_2e$ in direct implementation costs.[219] Private vehicle operating cost savings would amount to about $900 per $MTCO_2e$, supporting the LRTP's economic vitality goal.[220]

Reducing the cost of transit fares may have beneficial equity impacts if the reductions allow low-income people who previously were unable to afford the fare to use transit, expanding their mobility options. A new 2015 fare-reduction program in Seattle that cut fares by more than half for low-income riders could benefit thousands of riders. Cincinnati has established a similar program that helps 35,000 residents each year.[221]

Transit incentives may help with the Long-Range Transportation Plan goals of capacity management/mobility and clean air/clean communities as it encourages decreasing VMT. In general, transportation demand-management strategies such as transit incentives "address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[222]

Feasibility and Timing:

Fare reductions are considered to have high technical, institutional, and political feasibility nationally.[223] Transit fare-reduction programs are "generally well-accepted."[224]

Information on timing is not available.

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[219] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[220] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-40.

[221] National Public Radio, Seattle Cuts Public Transportation Fares For Low-Income Commuters, 2015, http://www.npr.org/sections/thetwo-way/2015/03/02/390279518/seattle-cuts-public-transportation-fares-for-low-income-commuters.

[222] USDOT, FHWA, *Reference Sourcebook*, p. 31.

[223] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[224] USDOT, FHWA, *Reference Sourcebook*, p. 86.

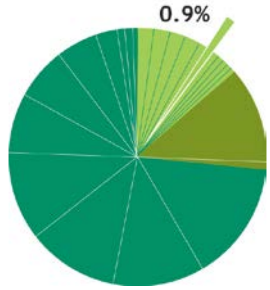
Data Needs:

There appears to be uncertainty about the magnitude of potential reductions with utilizing this strategy. Fare reductions of 50 percent have not been considered or studied for the Boston region or Massachusetts. The timing of benefits is unknown.

MPO Role:

The MPO could study the regional impacts of different levels of transit fare reduction, and recommend or support appropriate reductions. In the past, the Central Transportation Planning Staff of the MPO have studied proposed MBTA fare increases, so this is an area of MPO expertise. However, potential consideration of fare reduction (as opposed to fare increases) is dependent upon larger political decisions concerning funding of Massachusetts's public transportation system.

17) Individualized Marketing of Transportation Services



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	H
Technical Feasibility	M
Institutional Feasibility	M
Political Feasibility	H
MPO Role	Fund

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Economic Vitality

Description:

This GHG strategy, typically implemented at a neighborhood level, targets people who are open to alternative modes of transportation, then provides customized contact and transportation mode information. Individualized marketing is a relatively newer form of public information campaign that, in contrast to mass marketing, is tailored to specific individuals. While mass marketing can similarly achieve emissions reductions through travel behavior changes, individualized marketing has even greater GHG-cutting potential and is more cost-effective to implement.[225]

Individualized marketing programs use surveys to find individuals who are willing to consider alternative modes of transportation, and then supply "individualized contact and customized information" on transportation modes preferred by the selected respondents. According to Cambridge Systematics, the more thorough programs may provide "one-to-one personal interaction, such as travel planning advice," while more inexpensive programs "simply rely on survey responses to target print and web media information."[226] Selected neighborhoods in a number of US cities—including Cambridge, MA, Bellingham, WA, Cleveland, OH, Durham, NC, Portland, OR, and Sacramento, CA—have undertaken pilot projects.[227]

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[225] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[226] Cambridge Sytematics, Inc., Effects of Travel Reduction and Efficient Driving on Transportation: Energy Use and Greenhouse Gas Emissions , 2013, U.S. Department of Energy, http://www.camsys.com/pubs/TEF2.pdf (accessed December 2, 2015).

[227] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-93–5-95.

GHG Reduction:

If individualized marketing reached 10 percent of the population, it would have the potential to cut emissions by 0.14 to 0.28 percent.[228] VMT reductions of 2 to 8 percent for targeted populations have been achieved by pilot individualized marketing programs that included work and non-work travel. The VMT reductions from these pilot programs suggest that if individualized marketing campaigns could effect a 5 percent VMT reduction in 5 to 10 percent of the US population, the net effect could be as high as a 0.25 to 0.5 percent reduction in VMT.[229]

Costs and Benefits:

This strategy is highly cost-effective, with a direct cost-effectiveness of $90 per $MTCO_2e$.[230] Analysis of Portland's SmartTrips individualized marketing program estimates a cost of $29 per household reached, while a Seattle program cost only $10 to $15 per participant.[231]

This strategy has a number of co-benefits. Public information campaigns increase welfare by helping people make more informed transportation choices, improving their mobility and reducing their travel costs, supporting the MPO's capacity management/mobility and economic vitality goals. Air quality improvements are another benefit of people switching to less GHG-intensive modes.[232]

This strategy would support the Long-Range Transportation Plan goals of capacity management/mobility and clean air/clean communities as it encourages decreased VMT.

Feasibility and Timing:

Individualized marketing does not face any significant feasibility constraints as public information campaigns have a history of implementation;[233] this strategy has medium technical and institutional feasibility and high political feasibility.[234] Pilot projects have been conducted in selected US neighborhoods (this strategy

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[228] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[229] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-93–5-95.

[230] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[231] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-9 –5-95.

[232] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-93–5-95.

[233] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-93–5-95.

[234] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

was originally developed in Europe and Australia), including in Cambridge, Massachusetts.[235]

This strategy's timing of benefits is short term.[236]

Data Needs:

The GHG reduction potential of individualized marketing depends upon the proportion of the population that is: "1) willing to participate in individualized marketing programs, and 2) willing and able to make meaningful and permanent travel behavior shifts."[237] These parameters are unknown and this strategy has not been studied in Massachusetts or the Boston region.

MPO Role:

The MPO could provide funding support through its Clean Air and Mobility program for an existing or potentially new individualized marketing program to attain this strategy's greenhouse gas reductions. The MPO could also host elements of this program if it is web or internet-based, as well as support dissemination of information on the program through its standard outreach channels.

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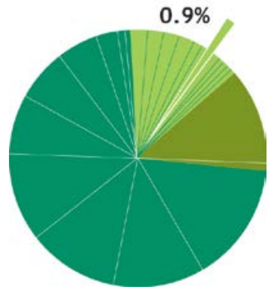
[235] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-93–5-95.

[236] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-37.

[237] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-93–5-95.

18) Truck Idling Reduction



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	H
Technical Feasibility	H
Institutional Feasibility	M
Political Feasibility	M
MPO Role	Fund or Study

LRTP Goal Addressed:

- Clean Air/Clean Communities
- Economic Vitality

Description:

Addressing GHG emissions from freight is important because nationwide freight trucks produce 22.5 percent of transportation sector GHGs.[238] Truck idling reduction can cost-effectively make modest cuts to greenhouse gas emissions. Ways to reduce truck idling include education, laws, technology, and land use decisions. Of these, installing idle reduction equipment (i.e., auxiliary power units) on all sleeper cabs is the most effective way to reduce GHG emissions.[239] Implementation of on-board idle technology would need to coordinate with state regulations.[240]

GHG Reduction:

If 26 to 100 percent of truck sleeper cabs were outfitted with on-board idle reduction technology, GHGs could be cut by 0.09 to 0.28 percent.[241] In Massachusetts 87 percent of freight movement occurs by truck and the Massachusetts Freight Plan projects that trucks will continue to play the largest

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[238] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013*, 2015, http://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2015-Main-Text.pdf (accessed December 2, 2015).

[239] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 4-41–4-45.

[240] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 34.

[241] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

role in freight movement in the future; GHG reduction strategies targeting truck emissions have significant potential depending on their scale.[242]

Costs and Benefits:

This strategy has a very high direct cost effectiveness of $20 per $MTCO_2e$.[243]

Truck idling reduction addresses the clean air/clean communities and economic vitality goals. The Transportation Research Board sums up the potentially "win-win" nature of this strategy— truck idling reduction "can provide modest total benefits with a low public investment cost while yielding net cost savings to truckers."[244] Similarly, this strategy supports the Massachusetts Freight Plan goal focused on environment and quality of life: "Ensure that the freight system preserves the environment and contributes to the quality of life in Massachusetts." [245] Diesel engines are a significant source of air pollutants such as nitrogen oxides (NOx) and particulate matter.

Feasibility and Timing:

Because only 26 percent of sleeper cab truck owners likely or very likely purchase idle reducing technologies, additional incentives are needed to attain full adoption of these technologies and reach the upper GHG benefits. Regulatory reforms, price incentives, and outreach programs can be used to reach widespread implementation. Examples of existing support for this strategy include EPA's SmartWay program which provides various financing programs for purchasing or leasing idle reduction technologies, and the Energy Improvement and Extension Act of 2008 removed the 12 percent excise tax on idle reduction devices for new trucks.

The feasibility of truck idling reduction is ranked high technically, low-to-medium institutionally, and medium-to-high politically.[246] The cost savings opportunities for truck operators make this strategy socially viable, and surveys on voluntary anti-idling campaigns for air quality purposes have found public support.[247, 248]

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[242] Massachusetts Department of Transportation, *Freight Plan*, 2010, https://www.massdot.state.ma.us/portals/17/docs/freightplan/MAFreightPlanSeptember2010v2.pdf (accessed December 2, 2015).

[243] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[244] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 34.

[245] Massachusetts Department of Transportation, *Freight Plan*, 2010, https://www.massdot.state.ma.us/portals/17/docs/freightplan/MAFreightPlanSeptember2010v2.pdf (accessed December 2, 2015).

[246] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[247] USDOT, FHWA, *Reference Sourcebook*, p. 212.

[248] USDOT, FHWA, *Reference Sourcebook*, p. 220.

The timing of benefits is short- to mid-term for this strategy.[249]

Data Needs:

Implementation of this strategy in the Boston region or Massachusetts has not been studied yet.

MPO Role:

The MPO could supply funding for the purchase of auxiliary power units (APU), as other MPOs seeking to reduce freight emissions have done. For example, the North Central Texas Council of Governments offers grant funding through the federal CMAQ program for projects that cut down on unnecessary truck idling. In 2008, $746,000 was split between four applicants, including $84,000 for two private companies to install APUs on the 18 trucks in their fleets (each company won separate grants). It is estimated that the APU would save about 9.8 tons of NOx during the life of the project.[250] The MPO could potentially use CMAQ funds to support such an initiative in the Boston area.

To reach the levels of implementation that match the ambitiousness of the strategy's national goals, the MPO would need to seek additional funding partners. Massachusetts currently has an Anti-Idling Law (MGL, Chapter 90, Section 16A, 310 CMR, Section 7.11 and MGL, Chapter 111, Sections 142A-142M) stating that no person should allow the unnecessary operation of the motor vehicle engine while the vehicle is stopped for a period in excess of five minutes. The regulation applies to all motor vehicles including trucks. Enforcement of this regulation is required for full compliance.

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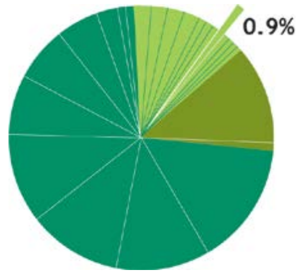
[249] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-35.

[250] Federal Highway Administration, U.S. Department of Transportation, Freight and Air Quality Handbook, Freight Management and Operations, http://www.ops.fhwa.dot.gov/publications/fhwahop10024/sect5.htm (accessed March 31, 2015).

19) Bicycle Improvements



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	H
Technical Feasibility	M
Institutional Feasibility	L
Political Feasibility	M
MPO Role	Fund or Study

LRTP Goals Addressed:

- Safety
- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Transportation Equity
- Economic Vitality

Description:

Infrastructure investments such as bike lanes, protected bike lanes, and off-road paths are at the center of bicycle improvements. At the same time, bicycle improvements include not only robust networks of bicycle facilities, but also supporting elements such as parking and cyclist training.[251]

GHG Reduction:

If comprehensive bicycle infrastructure is implemented in moderate to high-density urban neighborhoods, GHG reductions of 0.09-0.28 percent could be realized nationally,[252] with much higher benefits possible for the Boston region. This range depends on the extent of improvements as captured by the density of the network and the extent of on-street versus protected or off-street routes. [253] Facilities will provide the most advantages when they are in key locations where the greatest numbers of people can utilize them. *Moving Cooler* describes bicycling strategies at three levels of deployment, as cited below. The intervals refer to the distance between facilities in a grid system of parallel and perpendicular lanes and paths.[254]

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[251] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

[252] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-6.

[253] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

[254] Cambridge Systematics, *Moving Cooler*, p. 24.

1. Expanded Current Practice: Bike lanes and paths at one-mile intervals in high-density areas (>2,000 persons per square mile)
2. More Aggressive: Bike lanes and paths at one-half-mile intervals in high-density areas
3. Maximum Effort: Bike lanes and paths at one-quarter-mile intervals in high-density areas

In the Boston region, more than half of the municipalities exceed 2,000 persons per square mile and would be considered high-density areas. Because the US, on average, has lower population densities that do not support bicycle infrastructure, bicycle improvements could play a much bigger role in the Boston region's emissions than in the nation's emissions as a whole, with regional reductions greater than the 0.09 to 0.28 percent projected nationally.

Costs and Benefits:

Like pedestrian improvements, bicycle improvements are a highly cost-effective strategy, with an estimated cost-effectiveness of $80 to $210 per $MTCO_2e$.[255] The costs of different bicycle infrastructure vary. To build bicycle lanes in new or reconstructed roadways can be inexpensive, while a more expensive example is building a shared-use path.[256] Note that a somewhat more costly facility still could be just as cost-effective per ton of GHG reduced, than a cheaper but less robust facility as not all bicycle facilities hold equal weight in terms of attracting people to bicycle travel. Just as the extent of GHG reductions is dependent upon the extent of on-street versus protected or off-street routes, so too is cost effectiveness. When protected bicycle lanes are built on streets that previously had bike lanes, bicycle ridership has been found to increase 21 to 126 percent, with some of the increase attributed to new riders who otherwise would have used a different mode for their trip.[257] Studies have shown that peoples' associations of safety and comfort increase exponentially in protected bike lanes compared to conventional bike lanes, and that women and people of color stand to benefit the most from protected bike lanes in terms of becoming interested in cycling.[258,259]

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[255] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[256] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-6

[257] Portland State University and Alta Planning, *Lessons from the Green Lanes: Evaluating Protected Bike Lanes in the U.S.*, Executive Summary, 2014, National Institute for Transportation and Communities, http://ppms.otrec.us/media/project_files/NITC-RR-583_Executive_SummaryProtectedLanes.pdf (accessed March 25, 2015).

[258] Jennifer Dill, et. al., *Can Protected Bike Lanes Help Close the Gender Gap in Cycling?: Lessons from Five Cities*, 2014, http://docs.trb.org/prp/15-3481.pdf (accessed March 25, 2015).

Bike lanes and protected bike lanes in particular are associated with many safety advantages, not only for people biking but also for people walking. A review of 23 studies about bicycling injuries revealed that bicyclists are safest on bicycle facilities. Following the installation of many miles of new bike lanes in New York City, no increase in bike crashes resulted despite the increase in the number of cyclists. New York City's protected bike lanes reduced pedestrian injury rates by 12 to 52 percent. Another study found that protected bike lanes reduce bike-related intersection injuries by about 75 percent. [260]

Improvements to bicycle and pedestrian accommodations provide key public health and equity benefits. *Moving Cooler* states that investment in pedestrian and bicycle modes "can have substantial positive equity effects by increasing mobility for lower income groups and all those without significant access to vehicles." Those without significant access to vehicles include youth, the elderly, disabled persons, lower income individuals, or other individuals without driver permits. Having walking and biking as newly available transportation options would enhance the ability of individuals in these groups to access needed services.[261]

The Long-Range Transportation Plan goal of capacity management/mobility may also be supported by this strategy as it increases the percentage of population and places of employment with access to bicycle facilities and encourages a mode shift away from driving, decreasing VMT.

The LRTP's economic vitality goal may be well-supported by bicycle and pedestrian improvements. These modes offer substantial vehicle cost savings; when the costs of implementation are considered together with vehicle cost saving for users, there are net savings of \$600 to \$700 per $MTCO_2$.[262]

Bicycle and pedestrian facility improvement strategies also generate benefits in terms of increased physical activity and improved public health. Around 70 percent of American adults do not achieve recommended levels of physical activity, and sedentary lifestyles are associated with the rapid increase in the

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[259] PeopleForBikes and Alliance for Biking & Walking, *Building Equity*, Race, ethnicity, class, and protected bike lanes: An idea book for fairer cities, 2015, http://www.peopleforbikes.org/blog/entry/race-ethnicity-class-and-protected-bike-lanes-an-idea-book-for-fairer-citie (accessed March 25, 2015).

[260] People for Bikes, Statistics Library/Facilities Statistics, 2015, http://www.peopleforbikes.org/statistics/category/facilities-statistics (accessed December 2, 2015).

[261] Cambridge Systematics Inc., *Moving Cooler*, p. 74.

[262] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

percentage of Americans that are overweight and obese. Environments that are unsafe for walking and biking influence decisions not to choose these transportation options. However, if these modes can be made safer and allow more people to walk and bike, a great health benefit could be realized.[263,264]

Bicycle and pedestrian improvements, like transit, benefit from the presence of compact development. These non-motorized modes support transit use by making connections to and from transit stops, and, like transit, are "much more effective" where destinations are close together in densely developed areas.[265]

Feasibility and Timing:

Cities across the country have shown that high bicycle mode shares are possible where substantial investments in bicycle infrastructure are made, and not only where colleges and universities are located.[266] In the US, cities with the greatest share of bicycle commuters include Boulder, Colorado (11.1 percent) and Palo Alto, California (8.4 percent), which demonstrates that bicycling can represent significant mode share.[267] In Massachusetts, Somerville and Cambridge take the lead with more than 7 percent of residents commuting by bike.[268, 269] Abroad, countries that have built extensive cycling networks such as the Netherlands and Denmark have achieved bicycle mode shares of 27 and 18 percent, respectively.[270]

The trend in bicycling nationally and in Massachusetts has been one of rapid growth. Between 2005 and 2013, US states saw a 46 percent increase in the share of people commuting by bicycle; Massachusetts, with 0.8 percent of total commutes made by bicycle, was one of a handful of states that saw more than a 100-percent increase. In 2013, 1.9 percent of Boston's commuters biked to work,

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[263] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

[264] Centers for Disease Control and Prevention, "Obesity and Overweight," http://www.cdc.gov/nchs/fastats/obesity-overweight.htm (accessed March 6, 2015).

[265] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-6.

[266] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

[267] League of American Bicyclists, *Where We Ride: Analysis of bicycle commuting in American* cities, Report on 2013 American Community Survey Data by the League of American Bicyclists, http://bikeleague.org/content/updated-bike-commute-data-released (accessed March 6, 2015).

[268] City of Somerville, "Somerville #1 in Northeast, #5 in Nation for Bike Commuting," November 5, 2014, http://www.somervillema.gov/news/somerville-1-ne-5-nation-bike-commuting (accessed March 6, 2015).

[269] City of Cambridge Community Development Department, "Bicycle Trends," https://www.cambridgema.gov/CDD/Transportation/gettingaroundcambridge/bybike/biketrends.aspx (accessed March 6, 2015).

[270] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

more than double the statewide rate, representing a 100.7 percent increase in Boston between 2000 and 2013.[271]

Massachusetts incorporated Complete Streets principles in the 2006 MassDOT Highway Division Project Development and Design Guide, helping ensure that bicycle facilities are included in transportation projects. Featuring and prioritizing bicycle facilities in designs rather than simply accommodating them is a MassDOT GreenDOT goal.[272] Furthermore, the Massachusetts Legislature has recently implemented a Chapter 90-I Complete Streets Program that will provide $200 million in funding (12 percent of fiscal year 2016 capital investment) to communities to further Complete Streets goals such as increasing the safety and comfort of people walking and biking.[273, 274] This program could provide an important step towards achieving the comprehensive pedestrian improvements needed to meet the objectives of this strategy.

The feasibility of a bicycle improvement strategy at the national level is rated medium technically and politically and low institutionally.[275] This strategy's feasibility may be greater in Massachusetts than in other states as many Massachusetts cities are leaders in bicycle infrastructure. The League of American Bicyclists ranks Massachusetts as the tenth most bicycle-friendly state, with nine bicycle friendly communities: Cambridge, Somerville, Boston, Nantucket, Northampton, Arlington, Newton, Milton, and Lexington.[276] Furthermore, Hubway, one of a handful of bicycle share systems in the country, has been established in Boston, Brookline, Cambridge, and Somerville.

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[271] League of American Bicyclists, *Where We Ride: Analysis of bicycle commuting in American* cities, Report on 2013 American Community Survey Data by the League of American Bicyclists, http://bikeleague.org/content/updated-bike-commute-data-released (accessed March 6, 2015).

[272] Massachusetts Department of Transportation, *GreenDOT Implementation Plan*, 2012, https://www.massdot.state.ma.us/GreenDOT/GreenDOTReport/GreenDOTImplementationPlan.aspx (accessed December 15, 2015).

[273] Massachusetts Department of Transportation, MassDOT Capital Investment Plan Fiscal Year 2016, 2015, https://www.massdot.state.ma.us/Portals/0/docs/infoCenter/docs_materials/FY16_FinalCapitalBudget.pdf (accessed December 2, 2015).

[274] The 189th General Court of Massachusetts, General Laws, Chapter 90I Complete Streets Program, 2015, https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXIV/Chapter90I/Section1 (accessed December 2, 2015).

[275] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[276] League of American Bicyclists, "Award Database," http://bikeleague.org/bfa/awards#community (accessed March 4, 2015).

Most benefits from bicycle improvements could be realized within five to 20 years.[277]

Data Needs:

The GHG reduction potential of this strategy in the Boston region or Massachusetts has not been studied yet.

MPO Role:

The MPO has funded Hubway bicycle shares in Boston, Brookline, and Cambridge, as well as multi-use path construction in Somerville, through its Clean Air and Mobility program. This program also serves as a funding source for implementing small-scale roadway, intersection, bicycle, and pedestrian facilities that are recommended in MPO evaluations and studies. Prioritizing bicycle improvements in multimodal studies/projects where limited resources or right-of-way result in perceived competition between different modes also could help achieve further GHG reductions.

In the Boston MPO's recently adopted LRTP, *Charting Progress to 2040*, six percent of the LRTP's overall funding during the 25-year life of the plan was set aside in a Bicycle and Pedestrian program to fund these types of improvements. In addition, 33 percent has been set aside in a Complete Streets program for the life of the LRTP. Fifty-eight other MPOs have created and adopted a Complete Streets policy to strengthen their bicycle work, including the Metropolitan Washington Council of Governments (Washington, D.C. area), Wilmington Area Planning Council (Wilmington, DE area), Winston-Salem Urban Area Metropolitan Planning Organization (Winston-Salem, NC area), and Lancaster County Transportation Coordinating Committee (Lancaster, PA area).[278]

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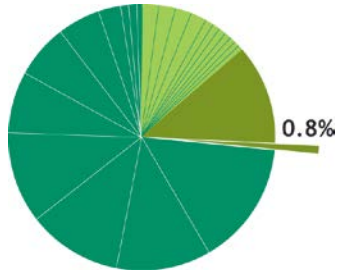
[277] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

[278] Smart Growth America and National Complete Streets Coalition, *The Best Complete Streets Policies of* 2014, 2015, http://www.smartgrowthamerica.org/documents/best-complete-streets-policies-of-2014.pdf (accessed March 27, 2015).

20) Information on Vehicles Purchase



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	L-M
Technical Feasibility	H
Institutional Feasibility	H
Political Feasibility	H
MPO Role	Publicize

LRTP Goal Addressed:

- Clean Air/Clean Communities
- Economic Vitality

Description:

The information about vehicle purchase strategy relies upon expanding the US EPA's freight-oriented SmartWay program and consumer information. SmartWay Transport is the US Environmental Protection Agency's flagship program for improving fuel efficiency and reducing greenhouse gases and air pollution from the transportation supply chain industry.[279] SmartWay is a voluntary collaboration between EPA and the freight industry that assigns a special designation to vehicles that perform well in terms of reducing greenhouse gas emissions and air pollution. While non-freight vehicle purchasers can also benefit from emissions information, this GHG reduction strategy specifically focuses on information for freight vehicles. Examples of key resources for consumers include EPA's Green Vehicle Guide and the US Department of Energy's (DOE) website, www.fueleconomy.gov.

GHG Reduction:

Expanding the EPA's freight-oriented SmartWay program and consumer information could reduce the transportation sector's greenhouse gas emissions by 0.09 to 0.23 percent.[280]

EPA credits the SmartWay program with saving 120.7 million barrels in oil and 16.8 billion in fuel costs between 2004 and 2014.[281] Nitrous oxide and particulate matter have been reduced as well. More than 2,500 partners nationally have

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[279] http://www.epa.gov/smartway/about/documents/basics/420f15033.pdf.

[280] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[281] U.S. Environmental Protection Agency, "SmartWay Program Highlights," http://www.epa.gov/smartway/about/documents/basics/420f14003.pdf (accessed March 4, 2015).

entered the SmartWay program, including large companies such as Wal-Mart and Tyson Foods.[282]

The DOE's website, www.fueleconomy.gov, has also been found to offer information leading to significant emissions reductions. DOE attributes a savings of 200 million gallons and a GHG reduction of 2 $MMTCO_2$ to the program in 2006 alone.[283]

Costs and Benefits:

While the direct cost-effectiveness of this strategy has not been quantified, costs of providing information are expected to be modest relative to other strategies that involve investment in infrastructure or services.[284]

The improved information made available to consumers is expected to result in cost savings, addressing the MPO's Economic Vitality goal.[285] The clean air/clean communities goal also is addressed by this strategy. EPA's SmartWay program "has been credited with saving truckers money and reducing fuel consumption and air pollution. EPA estimates that in 2004–2005, SmartWay projects saved 298 million gallons of fuel per year, saving truckers $850 million in fuel costs, and reduced NOx emissions by 25,000 tons and PM by 841 tons."[286]

Feasibility and Timing:

This strategy is promising, with high technical, institutional, and political feasibility.[287]

Most of this strategy's benefits could be realized in the short- to mid-term.[288]

Data Needs:

The GHG reduction potential of this strategy in the Boston region or Massachusetts is unknown.

MPO Role:

The MPO could support dissemination of information about vehicle purchase through a CMAQ-funded outreach program or via its standard information channels.

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[282] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-96–5-97.

[283] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-96–5-97.

[284] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-96–5-97.

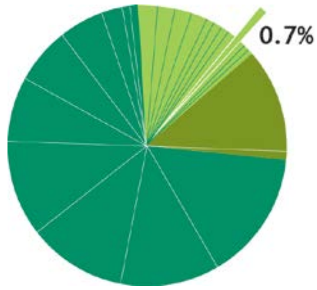
[285] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-96–5-97.

[286] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-96–5-97.

[287] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[288] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-37.

21) Rail Freight Infrastructure



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	H
Technical Feasibility	M
Institutional Feasibility	M
Political Feasibility	L-H
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Economic Vitality

Description:

Addressing GHG emissions from freight is important as nationwide trucks produce 22.5 percent of transportation sector GHGs.[289] Because moving goods by rail is more energy-efficient than moving goods by trucking, shifting or diverting freight from trucks to rail can reduce greenhouse gas emissions. Such a shift can be accomplished in several ways: infrastructure improvements that reduce the time and cost or increase the reliability of rail shipping, financial incentives or disincentives, and other policy and regulatory actions.[290] Currently 87 percent of all freight movement in Massachusetts is moved by truck, while only 5.0 percent is moved by rail.[291]

The elimination of rail system chokepoints has been compared to highway bottleneck improvements. Both can be accomplished with "infrastructure investments, operations strategies, or demand side improvements." Rail delay chokepoints can be located at terminals (e.g., intermodal facilities and fueling stations), bridges, tunnels, at-grade crossings, single-track segments, and tracks with low-capacity signal systems.[292]

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[289] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013*, 2015, http://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2015-Main-Text.pdf (accessed December 2, 2015).

[290] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 4-54–4-60.

[291] Massachusetts Department of Transportation, *Freight Plan*, 2010, https://www.massdot.state.ma.us/portals/17/docs/freightplan/MAFreightPlanSeptember2010v2.pdf (accessed December 2, 2015).

[292] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 4-54–4-60.

GHG Reduction:

Rail infrastructure investments in particular hold promise to cut GHGs. With "aspirational estimates of potential truck-rail diversion resulting from [a] major program of rail infrastructure investments," a GHG reduction of 0.01 to 0.22 percent can be attained. Public-sector investments may be necessary to relieve the capacity constraints in the nation's rail network; a study for the American Association of Railroads projected that the private sector is unable to invest the necessary amount itself.[293]

Costs and Benefits:

The direct cost-effectiveness is \$80 to \$200 per $MTCO_2e$. [294] Cost-effectiveness can "vary widely," in part because infrastructure costs can differ greatly.[295]

The LRTP goals of capacity management/mobility, clean air/clean communities, and economic vitality may gain from improved rail freight infrastructure as it potentially involves eliminating bottlenecks on the freight network and decreases VMT. This strategy also supports the Massachusetts Freight Plan goal focused on environment and quality of life: "Ensure that the freight system preserves the environment and contributes to the quality of life in Massachusetts." [296]

Feasibility and Timing:

Nationally, technical and institutional feasibility are medium for this strategy; political feasibility ranges from low to high.[297] In Massachusetts, the Freight Plan projects that trucks will continue to carry the majority of freight movements in the state for the foreseeable future, as shifting freight from truck to rail would be challenging and expensive, and would require coordination across regions. (Potentially, broader concerns about climate change could provide the impetus for a shift in spite of these challenges.) Nevertheless, the Freight Plan did recommend rail improvements as one of several freight investment priorities, to help increase the long-term sustainability of the state's freight system. [298]

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[293] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 4-54–4-60.

[294] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[295] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 4-54–4-60.

[296] Massachusetts Department of Transportation, *Freight Plan*, 2010, https://www.massdot.state.ma.us/portals/17/docs/freightplan/MAFreightPlanSeptember2010v2.pdf (accessed December 2, 2015).

[297] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[298] Massachusetts Department of Transportation, *Freight Plan*, 2010, https://www.massdot.state.ma.us/portals/17/docs/freightplan/MAFreightPlanSeptember2010v2.pdf (accessed December 2, 2015).

The timing of benefits for this strategy is medium-term, five-to-twenty years.[299]

Data Needs:

Implementation of a major program of rail infrastructure investments in the Boston region or Massachusetts has not been studied yet.

MPO Role:

The MPO could recommend or support increased rail freight infrastructure investments, and/or study the rail system to identify chokepoints. The MPO has previously studied freight movement in the region and provides funding annually for a freight-planning program.

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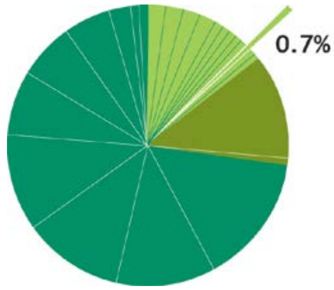
[299] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-35.

22) Parking Management



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	NA
Technical Feasibility	H
Institutional Feasibility	L
Political Feasibility	L
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Economic Vitality

Description:

Changes to parking pricing, supply, and other management techniques that establish disincentives to driving are together called "parking management." Parking management can be used to encourage people to walk, bike, take transit, or use other non-SOV modes to reach their destinations, and it can reduce parking search time. Examples of parking-management techniques include:[300]

- Reducing parking requirements for new development
- Designing and locating parking to encourage pedestrian travel for short local trips
- Charging workers for parking or allowing them to "cash-out" the value of used parking
- "Unbundling" parking costs from the cost of a residential lease or purchase
- Pricing to encourage "park-once" behavior
- Pricing to maintain vacant spaces in order to reduce parking search time
- Reducing on-street parking to leave more right-of-way for facilities for people walking or biking
- Using technology that allows drivers to efficiently locate parking spaces

[300] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-70–5-73.

Parking polices, especially off-street parking for new developments, also may be discussed as part of land use decisions as they are created within the same local planning framework.[301]

GHG Reduction:

Parking management could offer a moderate contribution to a portfolio of combined strategies. Cambridge Systematics and Eastern Research Group (2010) calculated a GHG reduction of 0.2 percent if all downtown workers pay for parking, with a $5-per-day average cost for those not already paying. Both the cost and supply of parking significantly affect travel behavior. A San Francisco Bay Area study found that transit mode shares increased by 50 percent for employees that had to pay for parking, compared to employees with free parking.[302] A US DOT study found that single-occupancy vehicle driving declined 16 to 81 percent when employers raised the price of parking to market rates.[303] In addition, a study of eight firms with nearly 1,700 employees by UCLA professor Donald Shoup found that businesses' VMT declined from 5 to 24 percent, with 12 percent on average, when they offered "parking cash-out" to employees and paid those employees who do not use parking facilities.[304]

Costs and Benefits:

Cost-effectiveness information is not available. Cambridge Systematics includes it in *Moving Cooler's* Low Cost strategy bundle, suggesting that it is lower cost in terms of net cost-effectiveness (weighing direct implementation costs against traveler savings).[305] Parking management can result in lowered costs for new development through the cost savings of constructing fewer parking spaces.[306]

Parking management may help with the Long-Range Transportation Plan goals of capacity management/mobility and clean air/clean communities as it encourages decreased VMT. In general, transportation demand-management strategies such as parking management "address a wide range of externalities associated with driving, including congestion, poor air quality, less livable

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[301] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-54.

[302] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-70–5-73.

[303] U.S. Department of Transportation, *Strategies to Reduce Greenhouse Gas Emissions from Transportation Sources*, 1998, Washington, D.C.

[304] Donald C. Shoup, Evaluating the effects of cashing out employer-paid pashing: Eight case studies, 1997, *Transport* Policy, Vol. 4, No. 4, p. 201-216.

[305] Cambridge Systematics, *Moving Cooler*, p. 62.

[306] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-70–5-73.

communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[307]

Feasibility and Timing:

As a national strategy, technical feasibility is ranked high, but institutional and political feasibility is ranked low.[308] These practices have been implemented nonetheless; for example, California State Law requires certain employers who provide subsidized parking to offer parking cash-out.[309] Parking polices may be received differently in different locations, with more social acceptability in urban areas, where drivers have more transportation choices and already experience parking fees. According to FHWA, although this perception may not be borne out in reality, increased parking costs may be perceived as inequitable to low-income drivers.[310]

After implementation, most of the benefits of parking management could be realized within five to twenty years.[311] Techniques such as market-rate pricing or a parking cash-out option can be implemented within one or two years, while reduced parking requirements in zoning many take years to have widespread effect.[312]

Data Needs:

Implementation of comprehensive parking management in the Boston region or Massachusetts has not been studied yet.

MPO Role:

The MPO could recommend or support municipal, Metropolitan Area Planning Council (MAPC), and State parking management techniques with funding or studies. The MAPC already offers parking technical assistance to interested communities in the Boston region, and supports legislation to bring state laws up-to-date with parking technology and parking-management best practices.[313] The MPO could potentially study parking pricing or on-street parking pricing policy in MPO municipalities.

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[307] USDOT, FHWA, *Reference Sourcebook*, p. 31.

[308] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.

[309] Air Resources Board, California Environmental Protection Agency, California's Parking Cash-Out Law, http://www.arb.ca.gov/planning/tsaq/cashout/cashout.htm (accessed March 19, 2015).

[310] USDOT, FHWA, *Reference Sourcebook*, p. 49.

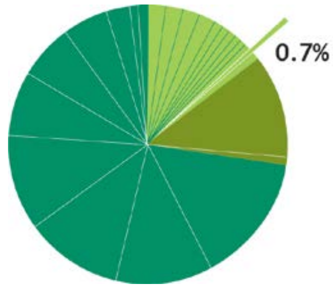
[311] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 3-36.

[312] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-70 – 5-73.

[313] Metropolitan Area Planning Council, Parking Resources, http://www.mapc.org/parking (accessed March 31, 2015).

The Boston Region MPO has the Community Transportation/Parking/Clean Air Mobility Program. Funding can be used to construct new parking spaces and it could fund new smart meters to manage existing parking spaces better through parking pricing. To increase private-sector adoption of parking management, the MPO also could conduct outreach about the benefits of parking management, potentially including this in a larger workplace TDM outreach program.

23) Carsharing



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	H
Technical Feasibility	H
Institutional Feasibility	M
Political Feasibility	H
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities

Description:

Carsharing describes a system where members pay to rent vehicles as needed on a per-trip hourly basis, either from companies or through peer-to-peer sharing. People who use carsharing services can access cars without car ownership, and they may choose to forego owning their own vehicles. In Cambridge, 70 percent of Zipcar members do not own a car, and 47 percent of Zipcar members who owned a car gave it up after joining Zipcar.[314] Carsharing services already operating in Massachusetts include Zipcar (which offers cars in more than 10 Boston area municipalities), Hertz 24/7, Enterprise CarShare, and peer-to-peer RelayRides. There are more than a million carshare members nationally.

GHG Reduction:

Subsidies for carsharing start-up and operations would save 0.05 to 0.20 percent of transportation GHG emissions. Studies in the US and Canada have found that after accounting for carshare members who drive more often because they did not previously own vehicles, emissions still declined 0.8 to 1.2 $MTCO_2$ per member per year.[315]

Carsharing is dependent on land use strategies as its effectiveness increases with higher densities.[316] In addition, parking management is “synergistic with carsharing: parking polices may increase the incidence of car sharing, and car

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[314] City of Cambridge, Community Development Department, “Carsharing in Cambridge, 2014: The missing link in sustainable transportation,” 2014, http://www.cambridgema.gov/~/media/Files/CDD/Transportation/carpoolandcarshare/Carshare%20in%20Cambridge%20web_20141126.ashx (accessed March 11, 2014).

[315] USDOT, FHWA, *Reference Sourcebook*, p. 53-59.

[316] Cambridge Systematics, Technical Appendices, *Moving Cooler*, p. B-78.

sharing programs (especially with designated parking spaces) may make parking policies more acceptable."[317] Zoning changes also may benefit carsharing; the City of Cambridge Community Development Department suggests that a state Chapter 90 carshare definition be added, and that carsharing be considered in parking requirements and residential district regulations.[318]

Costs and Benefits:

This strategy has very high cost-effectiveness, with a direct cost of less than $10 per $MTCO_2e$ saved.[319] Carsharing is one of the most cost-effective ways to reduce GHG emissions, although ultimately its maximum reductions are limited. The public sector can support this strategy not only through subsidies, but also through publicity and parking spaces.[320]

Carsharing may help with the Long-Range Transportation Plan goals of capacity management/mobility and clean air/clean communities since it encourages decreased in VMT. In general, carsharing "addresses a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[321]

Drivers who drive fewer miles than the break-even point—at which the cost of carsharing equals the cost of car ownership—would save money with carsharing, and are strong potential car sharing candidates.[322] This strategy may support the MPO's economic vitality goal.

Feasibility and Timing:

The Transportation Research Board rates the technical and political feasibility of carsharing subsidies as high, and the institutional feasibility as medium.[323] Social acceptability of car sharing is typically high, and though there may be resistance to reserving public parking spots for carsharing, this has not been significant.[324]

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[317] USDOT, FHWA, *Reference Sourcebook*, p. 50.

[318] City of Cambridge, Community Development Department, "Carsharing in Cambridge, 2014: The missing link in sustainable transportation," 2014, http://www.cambridgema.gov/~/media/Files/CDD/Transportation/carpoolandcarshare/Carshare%20in%20Cambridge%20web_20141126.ashx (accessed March 11, 2014).

[319] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[320] USDOT, FHWA, *Reference Sourcebook*, pp. 53-59.

[321] USDOT, FHWA, *Reference Sourcebook*, p. 31.

[322] USDOT, FHWA, *Reference Sourcebook*, pp. 53-59.

[323] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[324] USDOT, FHWA, *Reference Sourcebook*, p. 58.

Currently, Boston is launching a pilot program that would allow carsharing services to use 200 of the city's public parking spaces, and has collaborated with Zipcar to promote carsharing.

Information on timing is not available.

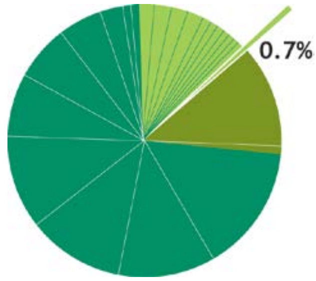
Data Needs:

The GHG reduction benefits of carsharing in the Boston region or Massachusetts have not been studied yet. In addition, information on this strategy's timing is not available.

MPO Role:

Expanding current public outreach programs such as MassRIDES to include carsharing more fully could be relatively simple. The MPO could fund carsharing outreach through existing programs, supported with CMAQ funds or coordinated with the MPO's other public involvement activities. The MPO also could study the role and use of carsharing in the MPO's transportation system, and how that role could be expanded.

24) Ridesharing



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	H
Technical Feasibility	H
Institutional Feasibility	L-H
Political Feasibility	H
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities

Description:

This strategy focuses on one type of workplace transportation-demand management—ridematching, carpooling, and vanpooling—which jointly may be called ridesharing. This strategy can reduce VMT by increasing vehicle occupancies for work trips. Carpooling is a formal or informal arrangement between at least two people to commute together in a private vehicle. Vanpooling typically involves five to fifteen people that choose to drive to work together in a van. Ridematching is a service that helps individuals find others with whom to carpool or vanpool. Dynamic ridesharing is a type of ridesharing that allows carpools to be formed on very short notice via internet technologies, mobile phones, etc. Another important piece of ridesharing is guaranteed ride home programs, in which employers reimburse employees for the costs of taxi rides or rental cars in the event of an emergency, or in a situation that requires them to leave work early or stay late.[325]

GHG Reduction:

Extensive rideshare outreach and support for ridematching, carpooling, and vanpooling has the potential to reduce GHG emissions by 0.0 to 0.2 percent.[326] One study of an early vanpool program in Massachusetts found a 66 percent average reduction in fuel use per participant. In Connecticut, a state vanpool program with more than 3,000 commuters in 2006, saved 2.8 million passenger miles and reduced GHG emissions by 1,250 $MTCO_2e$.[327]

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[325] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-87–5-91.

[326] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[327] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-87–5-91.

Costs and Benefits:

This strategy has a high estimated cost-effectiveness of \$80 per $MTCO_2e$. [328] Carpool programs realize a net savings when private vehicle operating costs are included in cost-effectiveness. Vanpool programs can cover most, if not all, of their purchase, operating, and administrative costs through subscription fees, as individuals save on vehicle operating costs. Some state and regional agencies subsidize vanpools to increase viability and ridership; the Denver Regional Council of Governments' fiscal-year 2009 budget set aside \$500,000 for vanpool subsidies.[329]

Ridesharing participants see lower travel costs and reduced stress, which are considered to more than offset the extra 10 to 12 minutes of travel time compared to driving alone.[330]

Ridesharing may help with the Long-Range Transportation Plan goals of capacity management/mobility and clean air/clean communities as it encourages decreased in VMT. In general, transportation demand-management strategies such as ridesharing "address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[331]

Feasibility and Timing:

MassRIDES has established a statewide ridematching program, NuRide, a free online tool that helps commuters find carpool matches and rewards them for greener trips.[332] This program is supported by the MassRIDES Emergency Ride Home Program that includes as many as four unexpected personal or family illness emergencies, or unexpected mandatory overtime events, per year. NuRide currently reduces GHG by 10,900 $MTCO_2e$.[333] The transportation management associations in the Boston region also offer ridesharing services; see "General Workplace TDM," above, for details.

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328 Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

329 Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-87–5-91.

330 Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-87–5-91.

331 USDOT, FHWA, *Reference Sourcebook*, p. 31.

332 Massachusetts Department of Transportation, MassRIDES, "Ridematching & Travel Rewards," http://www.commute.com/commuter-options/nuride (accessed March 9, 2015).

333 Massachusetts Department of Transportation, unpublished table of Transportation System GHG Reduction Strategies, n.d.

Ridesharing has high technical and political feasibility and low to medium institutional feasibility.[334] Ridesharing on a voluntary basis “is already a widely accepted strategy.”[335]

The timing of this strategy’s benefits is short, within five years.[336]

Data Needs:

Information about the current NuRide program is available through MassRIDES. The MPO could coordinate with MassRIDES and MassDOT to study further GHG reduction potential by offering additional services.

MPO Role:

MassRIDES and various TMAs in the Boston region currently provide ridesharing services. In order to gain further decreases in GHG emissions, the MPO could consider contributing publicity funding to MassRIDES or the TMAs through the Clean Air and Mobility program using CMAQ funds in order to expand their impact. If the MPO provided funding for a general workplace TDM program at the regional level, new ridesharing services could be provided. The MPO also could directly subsidize the costs of vanpools, as other regional (and state) agencies have done. The MPO could study the role and use of ridesharing in the MPO area, and how that role could be expanded.

Although not included as part of this literature review, transportation network companies should be mentioned as an important transportation alternative emerging in the region. Transportation network companies use online-enabled platforms to connect passengers with drivers using their personal, non-commercial vehicles. Some may refer to these services as ridesharing. Examples in the Boston area include Uber and Lyft. The MPO is currently studying the impacts of these types of services on the Boston Region’s transportation system.

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[334] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[335] USDOT, FHWA, *Reference Sourcebook*, p. 75.

[336] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, pp. 3-37.